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WASTEWATER ENGINEERING AND MANAGEMENT PLAN FOR BOSTON HARBOR-EA--ETC(U)

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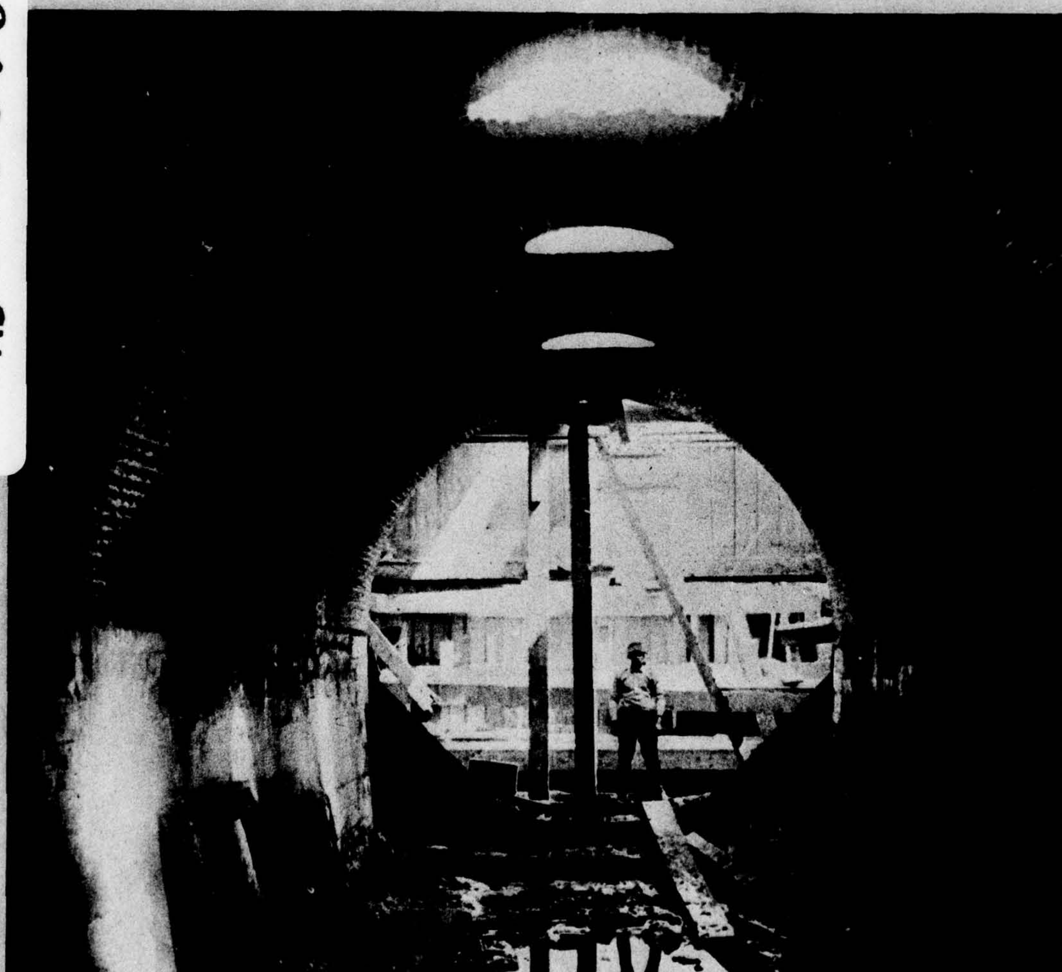
WASTEWATER ENGINEERING AND MANAGEMENT PLAN FOR BOSTON HARBOR - EASTERN MASSACHUSETTS METROPOLITAN AREA

EMMA STUDY

TECHNICAL DATA VOL. 2
ENGINEERING CRITERIA



OCTOBER 1975

INDEX TO EMMA STUDY REPORTS

<u>COVER PHOTO</u>

SAND CATCHER AFTER TAKING DOWN FORMS
APRIL 12, 1893, BELLE ISLE INLET
(NORTH METROPOLITAN TRUNK SEWER NEAR DEER ISLAND)

(6)

WASTEWATER ENGINEERING AND MANAGEMENT PLAN FOR BOSTON HARBOR – EASTERN MASSACHUSETTS METROPOLITAN AREA EMMA STUDY

TECHNICAL DATA [redacted] Volume 2.
ENGINEERING CRITERIA

FOR THE

METROPOLITAN DISTRICT COMMISSION

COMMONWEALTH OF MASSACHUSETTS

BY

METCALF & EDDY, INC.

(11) OCTOBER 1975

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REPORT

CHAPTER 1

INTRODUCTION

Report Structure

As shown on the inside cover, the study results are presented in a series of volumes.

This report ~~is~~ Technical Data Vol. 2, Engineering Criteria ~~and~~ covers the engineering criteria used in the project including the bases of estimating wastewater flows, sewerage needs, and costs.

Projections of sewerage needs and wastewater flows are made for each community. Several communities, however, have been broken down into smaller subdivisions in order to more accurately represent their effect on the MDC sewerage system. These are Brookline, Milton, Newton, and Boston.

CHAPTER 2

DRY-WEATHER FLOW

General

The purpose of the planning phase of the water pollution control project presented in Technical Data Vol. 1, Planning Criteria was to provide the data needed to form the basis for developing wastewater quantities expected from each community. Such wastewater quantities are then used to determine the size and extent of various conveyance and treatment facilities needed for water pollution control.

This chapter presents the methodology, bases and quantities determined.

Dry-Weather Flow Quantification Procedure

The approach to the quantification of dry-weather wastewater flows for the various design periods is shown on Figure 2-1.

The basic data used are: (1) population and industrial activity served by sewers which are used as a measure of future need; (2) water consumption experience which is used as a measure of estimating sewage flows; and (3) flow measurements along with the type and age of sewers which are used as a measure of infiltration/inflow allowance. Each of these parameters is discussed in the following chapters.

Total Dry-Weather Flow

As shown on Figure 2-1, the total dry-weather flow consists of sewage flow from domestic wastewater, industrial wastewater and infiltration. Projections by community for each of these are presented respectively in Chapters 4, 5 and 6.

During the progress of this study, various inventories for industrial wastes contributions were made in arriving at total dry-weather flow. The total flows presented in Table 2-1 are the final flows developed for determining facilities needed. However, in quantifying sewerage needs for the various concepts during the early stages of the study, flows were slightly different.

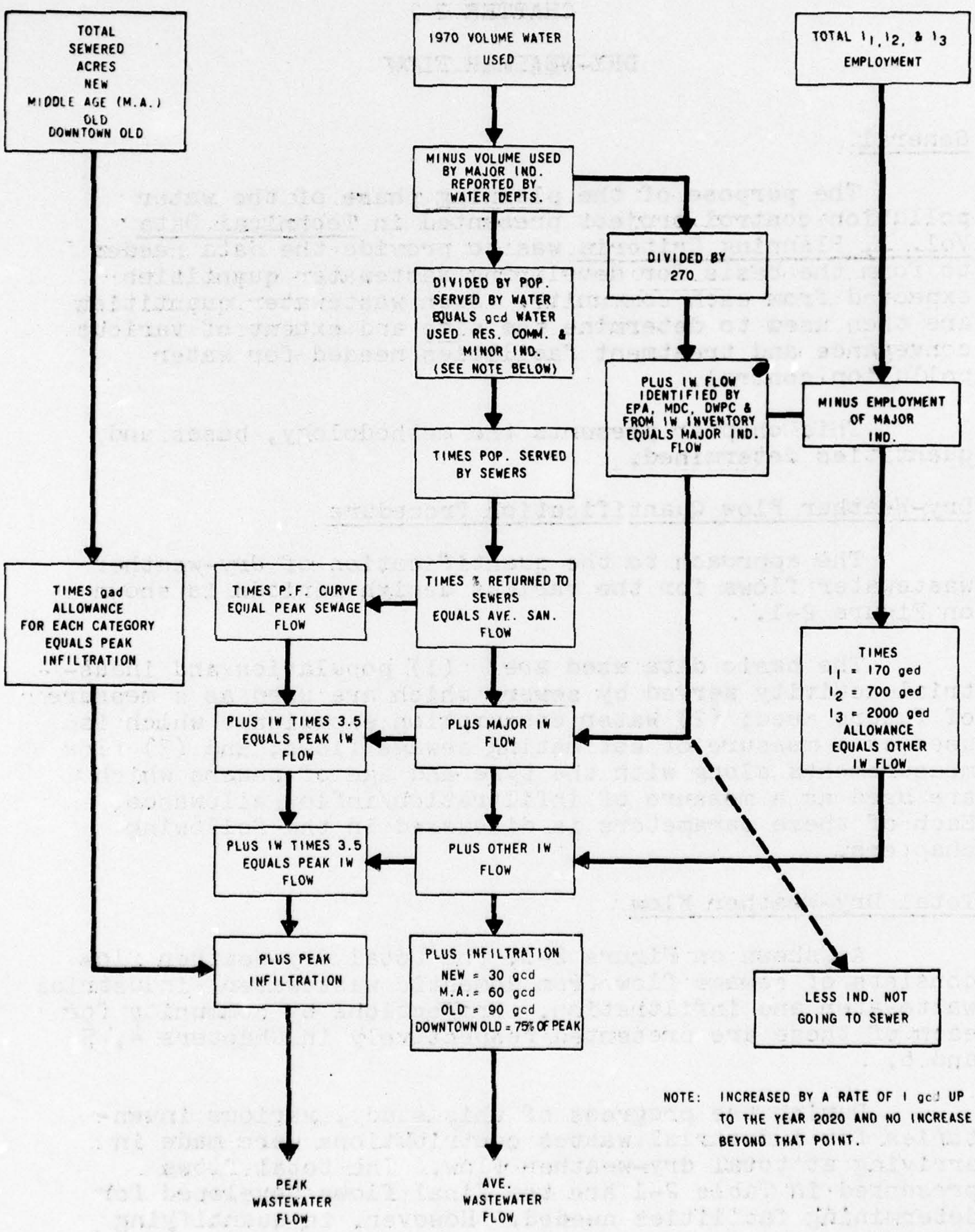


FIG. 2-1 FLOW QUANTIFICATION PROCEDURE

TABLE 2-1
TOTAL ESTIMATED FLOWS

COMM. NO.	COMMUNITY NAME		TOTAL ESTIMATED FLOWS (MGD) 1970 AVG.	1970 PEAK	2000 AVG.	2000 PEAK	2020 AVG.	2020 PEAK	2050 AVG.	2050 PEAK
1	ACTON		0.00	0.00	2.80	8.83	5.83	15.68	7.94	19.47
2	ARLINGTON	DI	8.94	18.48	10.34	21.99	11.00	23.90	9.31	21.56
3	ASHLAND	NI	0.92	3.59	2.79	9.51	3.87	12.29	4.40	13.52
4	AVON		0.00	0.00	0.99	3.64	1.47	5.03	1.61	5.29
5	BEDFORD	DI	1.42	5.73	3.14	11.19	3.55	12.45	2.97	11.16
6	BELLINGHAM		0.00	0.00	1.68	5.47	2.41	7.55	3.59	10.20
7	BELMONT	DI	3.53	9.31	4.69	11.68	4.99	12.75	4.98	12.69
8	BERLIN		0.00	0.00	0.00	0.00	1.27	4.65	2.97	9.16
9	BEVERLY		4.90	13.68	8.59	21.36	10.59	25.46	10.95	25.50
10	BILLERICA		0.92	4.10	4.57	13.14	6.93	18.44	6.64	17.76
11	BOLTON		0.00	0.00	0.00	0.00	0.91	3.58	3.93	11.09
12	BOXBOROUGH		0.00	0.00	0.00	0.00	1.20	4.35	2.94	8.62
13	BOXFORD		0.00	0.00	0.00	0.00	1.62	5.71	3.95	11.62
14	BRAINTREE	NI	4.55	13.60	6.82	17.76	7.96	20.04	8.00	19.53
15	BROOKLINE	DI	4.37	9.63	5.27	12.09	5.56	13.00	5.33	12.46
16	BROOKLINE	NI	6.33	11.57	7.59	14.86	8.16	16.43	7.96	16.00
17	BURLINGTON	DI	1.59	6.94	4.37	13.13	4.81	14.46	3.77	12.50
18	CAMBRIDGE	DI	28.72	65.53	31.14	65.22	32.42	68.66	28.80	64.38
19	CANTON	NI	2.65	9.89	5.75	17.47	7.36	20.63	8.00	20.79
20	CARLISLE		0.00	0.00	0.00	0.00	1.29	4.74	3.19	9.67
21	CHELMSFORD		0.00	0.00	4.12	12.22	7.89	20.79	8.22	21.34
22	CHELSEA	DI	6.41	13.43	4.64	11.85	4.51	12.15	4.78	12.58
23	COHASSET		0.06	0.48	1.02	3.86	2.03	6.76	2.29	7.56
24	CONCORD		1.17	4.28	3.28	9.93	5.88	15.91	8.19	20.71
25	DANVERS		3.88	13.74	6.20	18.80	7.50	21.63	6.69	20.15
26	DEDHAM	NI	4.04	12.29	5.24	15.28	5.75	16.69	4.65	14.80
27	DOVER		0.00	0.00	0.00	0.00	0.56	2.41	1.65	5.72
28	DUXBURY		0.00	0.00	0.00	0.00	0.75	3.10	2.13	7.25
29	ESSEX		0.00	0.00	0.39	1.79	1.24	4.55	2.11	6.94
30	EVERETT	DI	10.14	22.37	9.54	22.97	9.25	23.55	8.15	22.26
31	FRAMINGHAM	NI	8.73	24.64	13.88	32.88	15.96	36.50	15.72	36.16
32	FRANKLIN		1.86	6.75	3.78	11.80	6.01	17.06	8.00	21.23
33	GLOUCESTER		3.93	10.81	5.90	15.06	7.60	18.83	7.81	18.67
34	HAMILTON		0.00	0.00	0.86	3.37	2.28	7.44	3.57	10.72
35	HANOVER		0.00	0.00	2.09	6.94	3.21	9.91	4.01	11.57
36	HINGHAM	NI	0.57	2.48	2.49	8.34	4.29	12.96	4.37	13.11
37	HOLBROOK	NI	0.00	0.00	1.65	5.30	2.17	6.76	3.34	9.34
38	HOLLISTON		0.00	0.00	1.38	5.01	3.18	9.83	4.38	12.45
39	HOPKINTON		0.00	0.00	1.12	4.17	3.07	9.42	5.27	13.90
40	HUDSON		1.93	6.26	3.72	10.88	4.69	13.25	4.59	12.73
41	HULL		0.55	2.28	1.03	3.67	1.12	4.05	1.28	4.49
42	IPSWICH		0.69	2.70	2.33	7.38	3.53	10.54	4.52	12.81
43	LEXINGTON	DI	3.64	12.31	6.33	18.98	8.88	23.88	9.43	24.68
44	LINCOLN		0.00	0.00	0.61	2.54	1.40	4.98	3.45	10.19

TABLE 2-1
TOTAL ESTIMATED FLOWS

COMM. NO.	COMMUNITY NAME		TOTAL ESTIMATED FLOWS (MGD) 1970 AVG.	1970 PEAK	2000 AVG.	2000 PEAK	2020 AVG.	2020 PEAK	2050 AVG.	2050 PEAK
45	LITTLETON		0.00	0.00	0.98	3.83	2.83	9.13	4.71	13.22
46	LYNN		19.78	43.64	20.42	45.98	20.87	47.60	19.04	44.44
47	LYNNFIELD		0.00	0.00	1.68	5.84	2.68	8.50	3.36	9.99
48	MALDEN	DI	11.23	24.84	10.80	24.27	10.79	24.75	8.53	20.80
49	MANCHESTER		0.55	2.39	1.64	5.75	2.53	8.20	2.67	8.51
50	MARBLEHEAD		3.60	10.78	4.19	12.42	4.30	13.00	4.01	12.37
51	MARLBOROUGH		3.01	11.84	5.57	17.20	7.99	21.95	8.47	22.93
52	MARSHFIELD		0.07	0.33	3.32	10.05	5.61	15.62	6.92	18.45
53	MAYNARD		1.79	6.02	2.01	6.53	2.36	7.56	2.13	7.02
54	MEDFIELD		0.31	1.18	2.08	6.17	3.39	9.40	4.42	11.61
55	MEDFORD	DI	11.44	22.01	13.70	26.66	14.31	28.64	12.87	26.37
56	MEDWAY		0.11	0.43	0.98	3.71	2.14	7.07	2.96	8.84
57	MELROSE	DI	5.19	11.79	6.71	14.57	7.43	16.23	7.10	15.71
58	MIDDLETON		0.00	0.00	0.56	2.41	1.23	4.67	2.23	7.48
59	MILFORD		2.77	7.86	3.77	10.55	4.68	12.85	4.95	13.37
60	MILLIS		0.50	3.98	1.86	7.31	3.12	10.39	4.05	12.05
61	MILTON	DI	0.72	2.11	1.03	3.25	1.04	3.33	1.04	3.24
62	MILTON	NI	2.74	8.47	4.35	12.32	5.74	15.40	5.92	15.67
63	NAHANT		0.70	3.06	1.11	4.52	1.07	4.44	1.16	4.42
64	NATICK	NI	5.49	18.58	7.92	23.58	9.92	27.70	9.53	26.91
65	NEEDHAM	NI	4.20	13.46	6.94	18.38	8.78	21.89	9.54	22.43
66	NEWTON	DI	7.26	20.09	8.87	21.81	9.64	23.24	9.49	22.94
67	NEWTON	NI	8.46	24.57	10.33	27.25	11.58	29.07	11.84	29.37
68	NORFOLK		0.00	0.00	0.00	0.00	1.66	6.22	3.07	10.18
69	NORTH READING		0.00	0.00	1.58	5.32	2.67	8.23	3.43	9.78
70	NORTHBOROUGH		0.00	0.00	1.92	6.14	3.47	10.01	5.28	13.59
71	NORWELL		0.00	0.00	0.81	3.18	1.42	5.09	3.83	10.99
72	NORWOOD	NI	5.31	15.74	6.88	18.53	7.55	20.21	6.43	17.75
73	PEABODY		10.83	19.96	14.08	27.24	14.49	28.90	12.85	26.68
74	PEMBROKE		0.00	0.00	0.93	3.57	1.43	5.13	3.26	10.07
75	QUINCY	NI	17.60	36.97	20.61	42.65	23.04	47.50	21.05	42.20
76	RANDOLPH	NI	1.75	6.03	3.95	11.40	4.37	12.45	3.96	11.52
77	READING	DI	1.83	6.72	3.88	11.48	4.95	13.61	5.70	14.46
78	REVERE	DI	6.93	14.96	9.03	19.08	9.40	20.65	8.73	19.75
79	ROCKLAND		0.99	4.69	1.72	6.87	2.89	9.46	2.67	8.98
80	ROCKPORT		0.61	2.55	1.44	5.11	2.14	7.11	2.73	8.62
81	SALEM		8.77	21.58	8.90	21.84	8.77	21.93	6.97	18.65
82	SAUGUS		2.11	6.39	4.00	11.32	4.74	13.18	4.40	12.45
83	SCITUATE		0.22	1.36	1.97	6.61	3.51	10.66	4.23	12.31
84	SHARON		0.00	0.00	1.52	5.44	3.35	10.23	5.18	13.83
85	SHERBORN		0.00	0.00	0.00	0.00	0.83	3.32	1.84	6.25
86	SOMERVILLE	DI	19.64	34.51	16.54	32.72	17.48	35.07	17.35	35.00
87	SOUTHBOROUGH		0.00	0.00	1.01	3.76	2.22	7.03	3.96	10.67
88	STONEHAM	DI	2.76	8.17	3.38	9.77	3.46	10.32	3.58	10.37

TABLE 2-1
TOTAL ESTIMATED FLOWS

COMM. NO.	COMMUNITY NAME		TOTAL ESTIMATED FLOWS (MGD) 1970 AVG.	1970 PEAK	2000 AVG.	2000 PEAK	2020 AVG.	2020 PEAK	2050 AVG.	2050 PEAK
89	STOUGHTON	NI	1.52	6.06	4.83	14.03	6.55	17.74	6.76	17.90
90	STOW		0.00	0.00	0.00	0.00	0.70	2.88	1.86	6.28
91	SUDBURY		0.00	0.00	3.03	9.61	6.86	18.65	9.20	23.19
92	SWAMPSCOTT		2.02	6.15	3.18	8.52	3.64	9.70	3.97	10.19
93	TEWKSBURY		0.00	0.00	4.72	14.69	6.23	18.40	6.63	18.77
94	TOPSFIELD		0.00	0.00	0.58	2.45	1.88	6.32	3.00	9.28
95	WAKEFIELD	DI	4.74	14.66	7.39	20.10	8.61	22.83	9.30	23.61
96	WALPOLE	NI	6.74	24.57	8.62	28.95	10.98	33.98	11.89	35.08
97	WALTHAM	DI	13.51	41.06	18.91	47.62	19.95	49.78	18.17	45.51
98	WATERTOWN	DI	7.60	17.38	6.46	15.92	6.73	16.98	6.58	16.83
99	WAYLAND		0.00	0.00	2.56	8.43	5.63	15.97	6.90	18.50
100	WELLESLEY	NI	3.32	14.93	5.27	18.39	5.96	20.08	5.22	18.85
101	WENHAM		0.00	0.00	0.00	0.00	0.69	2.86	1.70	5.85
102	WESTBOROUGH		0.56	2.79	2.23	8.53	3.90	12.42	5.02	14.73
103	WESTFORD		0.00	0.00	1.17	4.47	2.76	9.03	6.10	16.18
104	WESTON		0.00	0.00	2.61	8.45	4.34	12.93	4.06	12.38
105	WESTWOOD	NI	0.47	2.01	2.82	8.67	3.81	11.23	4.04	11.71
106	WEYMOUTH	NI	2.92	8.19	7.04	17.10	8.38	20.05	8.24	19.64
107	WILMINGTON	DI	0.00	0.00	4.76	13.98	6.79	18.65	7.04	19.10
108	WINCHESTER	DI	3.94	12.38	4.91	14.48	5.02	15.19	4.67	14.61
109	WINTHROP	DI	3.10	6.27	2.53	6.31	2.28	6.32	2.62	6.90
110	WOBURN	DI	6.78	20.72	9.93	27.30	10.66	28.83	9.25	25.71
111	WRENTHAM		0.00	0.00	1.18	4.45	2.95	9.29	5.26	14.05
112	BOSTON PROPER	DI	39.74	103.75	47.88	114.97	57.98	133.01	63.09	137.09
113	BRIGHTON	DI	13.71	26.89	14.44	28.95	15.04	30.77	13.68	27.82
114	CHARLESTOWN	DI	6.10	16.89	5.25	14.24	5.61	15.58	5.40	15.17
115	DORCHESTER	DI	22.31	44.30	26.23	52.32	30.63	61.32	27.54	55.11
116	DORCHESTER	NI	3.54	9.19	3.39	9.29	3.68	10.30	3.25	9.10
117	EAST BOSTON	DI	7.58	15.17	7.77	16.19	8.07	17.17	7.74	16.42
118	FNWY-JMACA	DI	7.99	15.46	7.49	14.55	7.85	15.69	7.85	15.75
119	FNWY-JMACA	NI	1.92	4.09	1.92	4.28	1.99	4.63	2.01	4.76
120	HYDE PARK	NI	12.28	30.45	13.37	33.20	13.48	33.66	12.35	30.88
121	MATTAPAN	NI	4.59	9.68	5.65	12.86	5.82	13.52	5.31	12.19
122	ROSLINDALE	NI	4.76	9.75	7.12	15.69	8.10	18.20	10.86	24.15
123	ROXBURY	DI	24.13	52.83	22.58	49.94	23.76	53.31	23.58	52.86
124	SOUTH BOSTON	DI	15.32	38.09	14.29	34.98	14.47	35.89	13.81	33.91
125	WEST ROXBURY	NI	4.68	9.09	5.25	10.78	5.66	12.01	5.43	11.46

CHAPTER 3

POPULATION AND ECONOMIC ACTIVITY SERVED

General

Total regional projections of population and economic activity were made to the year 2050 and have been presented in Technical Data Vol. 1, Planning Criteria. Economic activity was reported in the form of employment. These projections recognize recent trends for a decreasing rate of growth in population and reflect regional totals believed to be realistic rather than the optimistic data generally used in sewerage planning. Similarly, economic projections were made recognizing decreasing activity in manufacturing regions but increasing activity in service-type employment.

Allocation of total regional population and economic activity to the various communities was carried out using the EMPIRIC Model and was based on factors such as accessibility, developability, and availability of utilities along with constraints.

The relative importance of each factor was established from evaluating the experiences of the 1960 to 1970 time period. Accessibility was measured by availability of transportation. The State Transportation Plan including highways and mass transportation was used as the future criteria.

Developability was measured by the land available for development in each community. Any area planned for open space retention for recreation, conservation, etc. or by a regional, state, or Federal agency was excluded from being available for development. Similarly, any land not suitable for development due to physical features was excluded from being available for development.

Projected sewerage system availability was based on regional and community utility plans. In those cases where no sewer systems existed and where no plans for sewerage had been made, the initiation of a sewerage system was based on comparing average densities of residential development with past experiences in sewerage service growth in EMMA communities.

Population Served

Seasonal Population Allowance. Twelve towns within the EMMA area were considered to have seasonal variations

in population that would be significant enough to produce fluctuations in wastewater flows. For these twelve towns, all of which are located along the seacoast, a 1970 experience value representing the relationship between seasonal and year-round population was developed as shown in Table 3-1. These values were decreased linearly to a value of 1.00 in the year 2000, at which time it was felt that the fluctuation in populations due to seasonal changes in the EMMA area would not be significant.

TABLE 3-1. ALLOWANCE FOR SEASONAL POPULATION IN 1970

Town	Ratio of seasonal to permanent population(1)
Cohasset	1.02
Duxbury	1.04
Gloucester	1.10
Hull	1.57
Ipswich	1.10
Manchester	1.08
Marblehead	1.03
Marshfield	1.23
Nahant	1.09
Rockport	1.22
Scituate	1.19
Winthrop	1.02

1. For all other communities in the EMMA area, the ratio is 1.

Sewered Population. The sewered population for 1970, the base year, was obtained from community data or from applicable engineering reports. Projections for future years were made through 2050.

In making projections for sewered population, past engineering and planning reports were reviewed. In addition, the percent of population served in each sewered EMMA community as related to the average density of residential development in that community was determined and is shown on Figure 3-1. This was used as an additional guide in estimating sewerage needs for the various years on the basis of projected density of sewers, and was especially necessary where no projections had been made earlier. On the basis of Figure 3-1, an average population density of about seven persons per residential acre

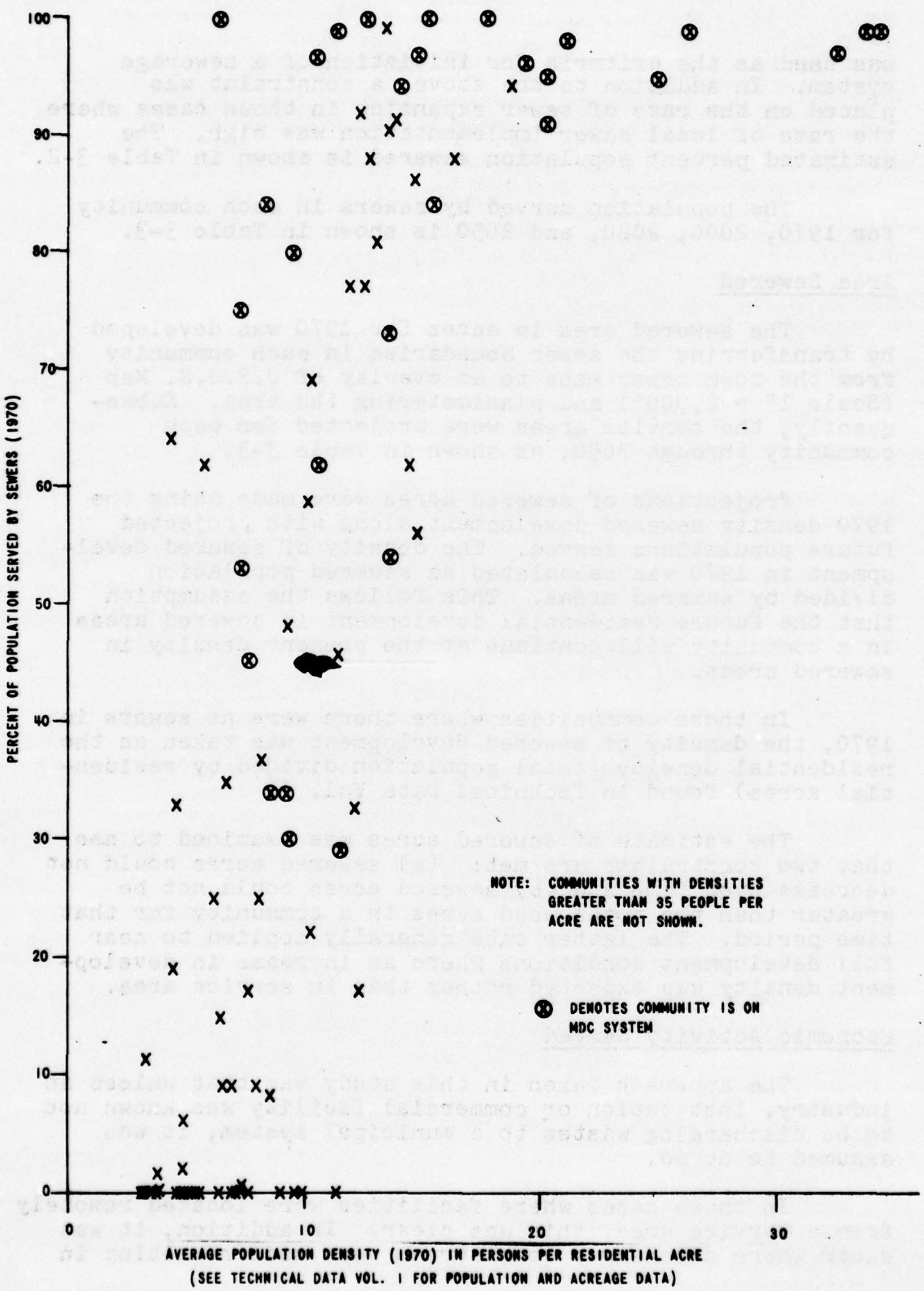


FIG. 3-1 PERCENT POPULATION SERVED VERSUS POPULATION DENSITY FOR COMMUNITIES IN THE EASTERN MASSACHUSETTS METROPOLITAN AREA

was used as the criteria for initiation of a sewerage system. In addition to the above, a constraint was placed on the rate of sewer expansion in those cases where the rate of local sewer implementation was high. The estimated percent population sewered is shown in Table 3-2.

The population served by sewers in each community for 1970, 2000, 2020, and 2050 is shown in Table 3-3.

Area Sewered

The sewered area in acres for 1970 was developed by transferring the sewer boundaries in each community from the town sewer maps to an overlay of U.S.G.S. Map (Scale 1" = 2,000') and planimetering the area. Subsequently, the service areas were projected for each community through 2050, as shown in Table 3-3.

Projections of sewered acres were made using the 1970 density sewered development along with projected future populations served. The density of sewered development in 1970 was calculated as sewered population divided by sewered areas. This follows the assumption that the future residential development in sewered areas in a community will continue at the present density in sewered areas.

In those communities where there were no sewers in 1970, the density of sewered development was taken as the residential density (total population divided by residential acres) found in Technical Data Vol. 1.

The estimate of sewered acres was examined to see that two constraints are met: (a) sewered acres could not decrease over time and (b) sewered acres could not be greater than the total used acres in a community for that time period. The latter case generally applied to near full development conditions where an increase in development density was expected rather than in service area.

Economic Activity Served

The approach taken in this study was that unless an industry, institution or commercial facility was known not to be discharging wastes to a municipal system, it was assumed to do so.

In those cases where facilities were located remotely from a service area, this was clear. In addition, it was clear where discharges to a stream were made resulting in

TABLE 3-2
PERCENT POPULATION SERVED

COMM. NO.	COMMUNITY NAME		1970	PERCENT POPULATION SERVED 2000	2020	2050
1	ACTON		0.	59.	95.	100.
2	ARLINGTON	DI	100.	100.	100.	100.
3	ASHLAND	NI	12.	90.	100.	100.
4	AVON		0.	80.	95.	100.
5	BEDFORD	DI	45.	90.	100.	100.
6	BELLINGHAM		0.	80.	90.	100.
7	BELMONT	DI	86.	100.	100.	100.
8	BERLIN		0.	0.	70.	100.
9	BEVERLY		88.	100.	100.	100.
10	BILLERICA		10.	80.	100.	100.
11	BOLTON		0.	0.	50.	100.
12	BOXBOROUGH		0.	0.	70.	100.
13	BOXFORD		0.	0.	70.	100.
14	BRAINTREE	NI	98.	100.	100.	100.
15	BROOKLINE	DI	100.	100.	100.	100.
16	BROOKLINE	NI	100.	100.	100.	100.
17	BURLINGTON	DI	49.	100.	100.	100.
18	CAMBRIDGE	DI	100.	100.	100.	100.
19	CANTON	NI	52.	95.	100.	100.
20	CARLISLE		0.	0.	45.	90.
21	CHELMSFORD		0.	65.	100.	100.
22	CHELSEA	DI	100.	100.	100.	100.
23	COHASSET		5.	65.	95.	100.
24	CONCORD		40.	75.	100.	100.
25	DANVERS		77.	95.	100.	100.
26	DEDHAM	NI	86.	100.	100.	100.
27	DOVER		0.	0.	29.	59.
28	DUXBURY		0.	0.	29.	59.
29	ESSEX		0.	45.	90.	100.
30	EVERETT	DI	100.	100.	100.	100.
31	FRAMINGHAM	NI	79.	100.	100.	100.
32	FRANKLIN		46.	80.	100.	100.
33	GLOUCESTER		58.	85.	95.	100.
34	HAMILTON		0.	50.	90.	100.
35	HANOVER		0.	90.	100.	100.
36	HINGHAM	NI	20.	70.	100.	100.
37	HOLBROOK	NI	0.	90.	100.	100.
38	HOLLISTON		0.	50.	90.	100.
39	HOPKINTON		0.	59.	95.	100.
40	HUDSON		77.	95.	100.	100.
41	HULL		33.	95.	100.	100.
42	IPSWICH		39.	90.	100.	100.
43	LEXINGTON	DI	77.	90.	100.	100.
44	LINCOLN		0.	40.	59.	90.
45	LITTLETON		0.	40.	90.	100.

TABLE 3-2
PERCENT POPULATION SERVED

COMM. NO.	COMMUNITY NAME		PERCENT POPULATION SERVED 1970	2000	2020	2050
46	LYNN		99.	100.	100.	100.
47	LYNNFIELD		0.	75.	90.	100.
48	MALDEN	DI	100.	100.	100.	100.
49	MANCHESTER		64.	90.	95.	100.
50	MARBLEHEAD		95.	100.	100.	100.
51	MARLBOROUGH		59.	80.	100.	100.
52	MARSHFIELD		2.	70.	90.	100.
53	MAYNARD		90.	95.	100.	100.
54	MEDFIELD		14.	80.	95.	100.
55	MEDFORD	DI	99.	100.	100.	100.
56	MEDWAY		4.	59.	95.	100.
57	MELROSE	DI	100.	100.	100.	100.
58	MIDDLETON		0.	35.	80.	100.
59	MILFORD		91.	95.	100.	100.
60	MILLIS		25.	80.	100.	100.
61	MILTON	DI	94.	100.	100.	100.
62	MILTON	NI	94.	100.	100.	100.
63	NAHANT		92.	100.	100.	100.
64	NATICK	NI	69.	90.	100.	100.
65	NEEDHAM	NI	86.	100.	100.	100.
66	NEWTON	DI	100.	100.	100.	100.
67	NEWTON	NI	100.	100.	100.	100.
68	NORFOLK		0.	0.	40.	70.
69	NORTH READING		0.	75.	95.	100.
70	NORTHBOROUGH		0.	80.	95.	100.
71	NORWELL		0.	50.	59.	100.
72	NORWOOD	NI	99.	100.	100.	100.
73	PEABODY		61.	97.	100.	100.
74	PEMBROKE		0.	50.	59.	100.
75	QUINCY	NI	100.	100.	100.	100.
76	RANDOLPH	NI	50.	95.	100.	100.
77	READING	DI	59.	90.	100.	100.
78	REVERE	DI	94.	100.	100.	100.
79	ROCKLAND		20.	50.	95.	100.
80	ROCKPORT		59.	90.	100.	100.
81	SALEM		96.	100.	100.	100.
82	SAUGUS		56.	83.	100.	100.
83	SCITUATE		10.	65.	90.	100.
84	SHARON		0.	50.	90.	100.
85	SHERBORN		0.	0.	40.	70.
86	SOMERVILLE	DI	100.	100.	100.	100.
87	SOUTHBOROUGH		0.	59.	90.	100.
88	STONEHAM	DI	95.	100.	100.	100.
89	STOUGHTON	NI	24.	90.	100.	100.
90	STOW		0.	0.	40.	70.

TABLE 3-2
PERCENT POPULATION SERVED

COMM. NO.	COMMUNITY NAME		1970	2000	2020	2050
91	SUDBURY		0.	59.	100.	100.
92	SWAMPSCOTT		94.	100.	100.	100.
93	TEWKSBURY		0.	80.	95.	100.
94	TOPSFIELD		0.	40.	90.	100.
95	WAKEFIELD	DI	88.	100.	100.	100.
96	WALPOLE	NI	32.	85.	100.	100.
97	WALTHAM	DI	75.	100.	100.	100.
98	WATERTOWN	DI	100.	100.	100.	100.
99	WAYLAND		0.	59.	100.	100.
100	WELLESLEY	NI	81.	100.	100.	100.
101	WENHAM		0.	0.	40.	75.
102	WESTBOROUGH		29.	75.	100.	100.
103	WESTFORD		0.	40.	70.	100.
104	WESTON		0.	80.	95.	100.
105	WESTWOOD	NI	34.	98.	100.	100.
106	WEYMOUTH	NI	51.	95.	100.	100.
107	WILMINGTON	DI	1.	85.	100.	100.
108	WINCHESTER	DI	100.	100.	100.	100.
109	WINTHROP	DI	100.	100.	100.	100.
110	WOBURN	DI	74.	100.	100.	100.
111	WRENTHAM		0.	50.	90.	100.
112	BOSTON PROPER	DI	100.	100.	100.	100.
113	BRIGHTON	DI	100.	100.	100.	100.
114	CHARLESTOWN	DI	100.	100.	100.	100.
115	DORCHESTER	DI	100.	100.	100.	100.
116	DORCHESTER	NI	100.	100.	100.	100.
117	EAST BOSTON	DI	100.	100.	100.	100.
118	FNWY-JMACA	DI	100.	100.	100.	100.
119	FNWY-JMACA	NI	100.	100.	100.	100.
120	HYDE PARK	NI	100.	100.	100.	100.
121	MATTAPAN	NI	100.	100.	100.	100.
122	ROSLINDALE	NI	100.	100.	100.	100.
123	ROXBURY	DI	100.	100.	100.	100.
124	SOUTH BOSTON	DI	100.	100.	100.	100.
125	WEST ROXBURY	NI	100.	100.	100.	100.

TABLE 3-3
EXISTING AND FUTURE AREAS AND POPULATIONS
SERVED BY PUBLIC SEWERS

COMM. NO.	COMMUNITY NAME		1970 SEWERED ACRES	1970 SEWERED POP.	2000 SEWERED ACRES	2000 SEWERED POP.	2020 SEWERED ACRES	2020 SEWERED POP.	2050 SEWERED ACRES	2050 SEWERED POP.
1	ACTON		0.	0.	2294.	19698.	4110.	40884.	4518.	56955.
2	ARLINGTON	DI	3000.	53557.	2999.	54012.	2999.	53039.	2999.	45117.
3	ASHLAND	NI	250.	1065.	2403.	15781.	3099.	22172.	3630.	26378.
4	AVON		0.	0.	754.	6999.	1004.	9946.	1051.	11443.
5	BEDFORD	DI	1400.	6080.	3888.	16889.	4093.	17779.	4093.	14266.
6	BELLINGHAM		0.	0.	1496.	13823.	2040.	17811.	2573.	26507.
7	BELMONT	DI	2000.	24350.	1999.	27992.	1999.	27215.	1999.	27236.
8	BERLIN		0.	0.	0.	0.	1337.	9360.	3265.	22855.
9	BEVERLY		3525.	33765.	5618.	57841.	6169.	66130.	6169.	69850.
10	BILLERICA		1000.	3164.	4268.	34312.	5839.	48547.	5839.	47116.
11	BOLTON		0.	0.	0.	0.	868.	6082.	3135.	29417.
12	BOXBOROUGH		0.	0.	0.	0.	1262.	9302.	2412.	22760.
13	BOXFORD		0.	0.	0.	0.	1654.	11580.	4226.	29586.
14	BRAINTREE	NI	4400.	34351.	4825.	47577.	5141.	52213.	5227.	54724.
15	BROOKLINE	DI	860.	30662.	859.	31714.	859.	29894.	859.	27963.
16	BROOKLINE	NI	2330.	27515.	2474.	33202.	2474.	33474.	2474.	31509.
17	BURLINGTON	DI	3900.	10770.	5386.	33058.	5401.	32344.	5401.	24632.
18	CAMBRIDGE	DI	3400.	100393.	3399.	106841.	3399.	103754.	3399.	91271.
19	CANTON	NI	1650.	8892.	4948.	32903.	5882.	42892.	6248.	51415.
20	CARLISLE		0.	0.	0.	0.	1313.	9196.	3507.	24554.
21	CHELMSFORD		0.	0.	4130.	28968.	7088.	51430.	7088.	53778.
22	CHELSEA	DI	1000.	30643.	999.	20534.	999.	18764.	999.	19748.
23	COHASSET		150.	347.	1198.	8391.	2162.	15138.	2601.	16819.
24	CONCORD		700.	6459.	2393.	22081.	4274.	39445.	6141.	56671.
25	DANVERS		3500.	20197.	4769.	33681.	5167.	39199.	5167.	34778.
26	DEDHAM	NI	2700.	23774.	3315.	29191.	3410.	29860.	3410.	24125.
27	DOVER		0.	0.	0.	0.	639.	4474.	1801.	12607.
28	DUXBURY		0.	0.	0.	0.	658.	4612.	1913.	13394.
29	ESSEX		0.	0.	433.	3032.	1325.	9276.	2312.	16188.
30	EVERETT	DI	1300.	42478.	1299.	35551.	1299.	31686.	1299.	26839.
31	FRAMINGHAM	NI	7000.	50597.	9141.	84486.	9511.	91816.	9511.	90380.
32	FRANKLIN		1000.	8310.	2742.	22796.	4474.	37190.	6270.	52109.
33	GLOUCESTER		850.	16485.	1578.	30615.	2009.	38972.	2210.	42869.
34	HAMILTON		0.	0.	972.	6809.	2449.	17149.	3821.	26750.
35	HANOVER		0.	0.	2382.	16679.	3334.	23339.	3879.	30144.
36	HINGHAM	NI	650.	3764.	3336.	19321.	5390.	31218.	5571.	32196.
37	HOLBROOK	NI	0.	0.	1240.	13270.	1459.	15622.	2203.	25492.
38	HOLLISTON		0.	0.	1444.	10108.	3299.	23094.	4365.	33043.
39	HOPKINTON		0.	0.	1291.	9043.	3232.	23181.	4341.	40550.
40	HUDSON		1350.	12384.	2744.	25181.	3301.	30283.	3413.	31310.
41	HULL		350.	3282.	805.	7554.	815.	7367.	870.	8252.
42	IPSWICH		450.	4192.	1743.	16248.	2425.	22598.	3187.	29694.
43	LEXINGTON	DI	4400.	24557.	6921.	39174.	7550.	51839.	7611.	55546.

TABLE 3-3
EXISTING AND FUTURE AREAS AND POPULATIONS
SERVED BY PUBLIC SEWERS

COMM. NO.	COMMUNITY NAME		1970 SEWERED ACRES	1970 SEWERED POP.	2000 SEWERED ACRES	2000 SEWERED POP.	2020 SEWERED ACRES	2020 SEWERED POP.	2050 SEWERED ACRES	2050 SEWERED POP.
44	LINCOLN		0.	0.	801.	5608.	1591.	11143.	3918.	27431.
45	LITTLETON		0.	0.	799.	5598.	2611.	18279.	3655.	32128.
46	LYNN		4250.	89375.	4250.	83738.	4250.	80589.	4250.	73907.
47	LYNNFIELD		0.	0.	1787.	12514.	2482.	18270.	2741.	23069.
48	MALDEN	DI	2600.	56127.	2599.	50987.	2599.	48103.	2599.	39323.
49	MANCHESTER		400.	3296.	1295.	10680.	1930.	15912.	2157.	17319.
50	MARBLEHEAD		2050.	20230.	2050.	20808.	2050.	19929.	2050.	18978.
51	MARLBOROUGH		3000.	16761.	4125.	30994.	4876.	43583.	5249.	47032.
52	MARSHFIELD		25.	304.	3494.	24458.	5284.	36992.	6318.	45563.
53	MAYNARD		850.	8739.	1108.	11391.	1253.	12886.	1253.	11788.
54	MEDFIELD		100.	1473.	1064.	15687.	1617.	23834.	2170.	31976.
55	MEDFORD	DI	2750.	63764.	2749.	67330.	2749.	65266.	2749.	59591.
56	MEDWAY		16.	313.	1032.	7657.	2106.	15580.	2509.	22262.
57	MELROSE	DI	2000.	33198.	1999.	38120.	1999.	39027.	1999.	37523.
58	MIDDLETON		100.	0.	343.	2402.	1045.	7317.	2055.	14386.
59	MILFORD		1500.	17610.	1875.	22012.	2226.	26141.	2438.	28629.
60	MILLIS		1100.	1448.	2094.	11172.	2982.	19328.	3555.	27307.
61	MILTON	DI	230.	4867.	248.	5096.	248.	5118.	259.	5498.
62	MILTON	NI	2510.	20691.	3789.	31235.	4241.	37661.	4241.	38847.
63	NAHANT		500.	3784.	500.	3844.	500.	3700.	500.	4729.
64	NATICK	NI	3800.	21422.	5416.	37465.	5739.	46279.	5739.	44387.
65	NEEDHAM	NI	3600.	25549.	4685.	44124.	5176.	53244.	5176.	59811.
66	NEWTON	DI	4120.	41086.	4119.	48872.	4119.	50191.	4119.	49667.
67	NEWTON	NI	6260.	49987.	6259.	56962.	6259.	60904.	6259.	62335.
68	NORFOLK		0.	0.	0.	0.	874.	6120.	2386.	16703.
69	NORTH READING		0.	0.	1600.	13120.	2396.	19952.	2651.	26013.
70	NORTHBOROUGH		0.	0.	1517.	14907.	2395.	25025.	2965.	38945.
71	NORWELL		0.	0.	957.	6705.	1523.	10661.	3185.	28254.
72	NORWOOD	NI	3200.	30549.	3338.	38051.	3424.	39100.	3424.	34804.
73	PEABODY		2800.	29809.	5086.	55679.	5086.	56155.	5086.	50619.
74	PEMBROKE		0.	0.	1062.	7434.	1494.	10463.	3351.	23457.
75	QUINCY	NI	5250.	87966.	5249.	102925.	5249.	111380.	5249.	102912.
76	RANDOLPH	NI	1800.	13517.	3612.	30803.	3612.	31290.	3612.	28911.
77	READING	DI	2100.	13523.	3678.	29008.	3706.	34318.	3706.	41060.
78	REVERE	DI	1800.	40569.	1848.	46382.	1848.	44477.	1848.	41544.
79	ROCKLAND		1650.	3143.	2508.	9706.	2588.	18205.	2588.	16588.
80	ROCKPORT		400.	3381.	1133.	9583.	1587.	13423.	2057.	17393.
81	SALEM		2050.	38920.	2050.	37627.	2050.	35416.	2050.	28644.
82	SAUGUS		1250.	14069.	2174.	24474.	2408.	27113.	2408.	25534.
83	SCITUATE		450.	1697.	2165.	15157.	3535.	24745.	4343.	30406.
84	SHARON		0.	0.	1535.	10747.	3439.	24489.	4226.	39180.
85	SHERBORN		0.	0.	0.	0.	801.	5608.	1992.	13948.
86	SOMERVILLE	DI	2300.	88732.	2300.	69063.	2300.	68590.	2300.	68007.

TABLE 3-3
EXISTING AND FUTURE AREAS AND POPULATIONS
SERVED BY PUBLIC SEWERS

COMM. NO.	COMMUNITY NAME		1970 SEWERED ACRES	1970 SEWERED POP.	2000 SEWERED ACRES	2000 SEWERED POP.	2020 SEWERED ACRES	2020 SEWERED POP.	2050 SEWERED ACRES	2050 SEWERED POP.
87	SOUTHBOROUGH		0.	0.	871.	7220.	1620.	15638.	2056.	28924.
88	STONEHAM	DI	1900.	19675.	1972.	21347.	1972.	19984.	1972.	21142.
89	STOUGHTON	NI	1000.	5643.	3817.	32823.	4301.	41994.	4569.	45016.
90	STOW		0.	0.	0.	0.	685.	4799.	2031.	14218.
91	SUDBURY		0.	0.	2975.	20830.	6487.	45412.	8060.	62074.
92	SWAMPSCOTT		1150.	12773.	1150.	17170.	1172.	18158.	1197.	19999.
93	TEWKSBURY		0.	0.	2839.	25777.	3793.	34204.	4018.	39306.
94	TOPSFIELD		0.	0.	671.	4697.	2056.	14395.	3237.	22665.
95	WAKEFIELD	DI	2250.	22353.	2730.	35814.	2884.	39887.	2941.	44840.
96	WALPOLE	NI	1100.	5807.	5421.	30071.	6634.	44666.	7223.	54203.
97	WALTHAM	DI	4300.	46186.	5341.	85014.	5341.	84883.	5341.	79553.
98	WATERTOWN	DI	2100.	39295.	2100.	31693.	2100.	30607.	2100.	29791.
99	WAYLAND		0.	0.	2424.	16972.	5235.	36650.	6002.	45799.
100	WELLESLEY	NI	6200.	22718.	6199.	31646.	6199.	32690.	6199.	28959.
101	WENHAM		0.	0.	0.	0.	709.	4963.	1745.	12579.
102	WESTBOROUGH		1100.	3778.	4246.	15594.	4924.	26337.	5474.	34947.
103	WESTFORD		0.	0.	952.	6665.	2565.	17956.	5144.	44786.
104	WESTON		0.	0.	2457.	17202.	3720.	26041.	3720.	24406.
105	WESTWOOD	NI	600.	4333.	3176.	22941.	3820.	27591.	4112.	29702.
106	WEYMOUTH	NI	3050.	27830.	5757.	57699.	5838.	61102.	5838.	60878.
107	WILMINGTON	DI	50.	171.	2887.	27165.	3592.	36967.	3592.	38515.
108	WINCHESTER	DI	2550.	22211.	2549.	25149.	2549.	23737.	2549.	21875.
109	WINTHROP	DI	800.	20335.	800.	14604.	800.	12136.	800.	13728.
110	WOBURN	DI	2100.	27680.	3819.	50346.	3916.	51630.	3916.	45247.
111	WRENTHAM		0.	0.	1003.	7227.	2531.	19899.	3498.	37952.
112	BOSTON PROPER	DI	1480.	67135.	1480.	86705.	1480.	121106.	1480.	181190.
113	BRIGHTON	DI	1990.	63618.	1990.	53888.	1990.	48938.	1990.	37185.
114	CHARLESTOWN	DI	480.	15417.	480.	11035.	480.	9867.	480.	7418.
115	DORCHESTER	DI	2900.	112065.	2900.	121221.	2900.	139514.	2900.	114173.
116	DORCHESTER	NI	410.	25655.	410.	13913.	410.	12904.	410.	9370.
117	EAST BOSTON	DI	1120.	38830.	1120.	29012.	1120.	26750.	1120.	23135.
118	FNWY-JMACA	DI	1290.	38328.	1290.	22444.	1290.	20944.	1290.	19925.
119	FNWY-JMACA	NI	490.	9973.	490.	6078.	490.	5327.	490.	4410.
120	HYDE PARK	NI	2660.	38264.	2660.	39133.	2660.	34458.	2660.	24913.
121	MATTAPAN	NI	960.	37232.	960.	35248.	960.	31222.	960.	27919.
122	ROSLINDALE	NI	1300.	28214.	1300.	42031.	1300.	44614.	1300.	66489.
123	ROXBURY	DI	2290.	98203.	2290.	58507.	2290.	54254.	2290.	52223.
124	SOUTH BOSTON	DI	1470.	43145.	1470.	30517.	1470.	25618.	1470.	23176.
125	WEST ROXBURY	NI	1450.	24974.	1450.	24021.	1450.	23852.	1450.	21483.

issuance of a permit. The prime area for interpretation was left to conditions where an on-lot disposal system existed within a service area.

In making projections, it was assumed that all economic activities would be discharging to public sewer systems by the year 2000.

CHAPTER 4

WATER CONSUMPTION AND SEWAGE FLOW

General

This chapter describes the method and the associated data used for estimating sewage flows projected for the EMMA communities.

An analysis of water consumption data was selected as the basis for sewage flow quantification. This procedure was used throughout the EMMA area including communities presently served by the Deer and Nut Island treatment plants. Although flows are measured and recorded at the two treatment plants, the effects of dissimilar flow characteristics from communities, overflows, salt water intrusion, and infiltration negate the use of this data for determining flows from each community.

Water Use

Total annual volumes of water used by each EMMA community with public water supply systems were obtained from the various municipalities and from MDC. Water use in this report represents water used by the community or total water produced less unaccounted for water. In those cases where unaccounted for water was not known, the total volume of water produced by or delivered to a community was reduced by 20 percent to account for losses.

The total volume of water use by community during 1970 is shown in Table 4-1.

Major Individual Water Use. Prior to estimating the per capita water use by each community, major users of municipal water known to community water departments were listed and their volume was subtracted from the total municipal water use. These generally were industries, but also included major institutions and commercial establishments.

The total volume of water drawn from municipal systems by major users in each community during 1970 is shown in Table 4-1.

Per Capita Water Use. Water use in gcd (gallons per capita per day) resulting from this analysis was compared with criteria used in community engineering reports and

TABLE 4-1. WATER USE IN 1970

No.	Community	Total volume used, gal. x 10^3	Major users, gal. x 10^3
1	Acton	902	20
2	Arlington	5,481	81
3	Ashland	1,062	384
4	Avon	334	70
5	Bedford	1,268	327
6	Bellingham	649	102
7	Belmont	2,511	112
8	Berlin		
9	Beverly	2,766	255
10	Billerica	2,269	910
11	Bolton		
112-125	Boston	113,000	32,567
12	Boxborough		
13	Boxford		
14	Braintree	2,569	156
15,16	Brookline	5,901	741
17	Burlington	2,013	414
18	Cambridge	18,685	7,223
19	Canton	1,996	366
20	Carlisle		
21	Chelmsford	1,926	258
22	Chelsea	2,617	597
23	Cohasset	527	-

TABLE 4-1 (Continued). WATER USE IN 1970

No.	Community	Total volume used, gal. x 10^3	Major users, gal. x 10^3
24	Concord	1,403	290
25	Danvers	2,439	207
26	Dedham	2,568	186
27	Dover		
28	Duxbury	711	-
29	Essex		
30	Everett	6,400	3,732
31	Framingham	7,151	476
32	Franklin	1,325	34
33	Gloucester	2,766	336
34	Hamilton	430	-
35	Hanover	723	-
36	Hingham	1,345	30
37	Holbrook		
38	Holliston		
39	Hopkinton		
40	Hudson	7,873	110
41	Hull	826	7
42	Ipswich	924	146
43	Lexington	3,607	371
44	Lincoln		
45	Littleton	532	86
46	Lynn	13,699	6,178

TABLE 4-1 (Continued). WATER USE IN 1970

No.	Community	Total volume used, gal. x 10^3	Major users, gal. x 10^3
47	Lynnfield	395	-
48	Malden	5,534	831
49	Manchester	453	-
50	Marblehead	2,097	21
51	Marlborough	2,542	205
52	Marshfield	1,502	-
53	Maynard	741	8
54	Medfield	537	89
55	Medford	6,464	326
56	Medway	527	39
57	Melrose	2,402	231
58	Middleton	207	43
59	Milford	1,435	44
60	Millis	510	202
61,62	Milton	2,043	112
63	Nahant	449	-
64	Natick	4,680	1,370
65	Needham	2,627	41
66,67	Newton	8,523	1,623
68	Norfolk	65	732
69	North Reading	741	-
70	Northborough	567	49
71	Norwell	398	-

TABLE 4-1 (Continued). WATER USE IN 1970

No.	Community	Total volume used, gal. x 10^3	Major users, gal. x 10^3
72	Norwood	3,120	1,037
73	Peabody	5,475	1,404
74	Pembroke		
75	Quincy	8,194	307
76	Randolph		
77	Reading	1,876	282
78	Revere	3,160	356
79	Rockland	916	90
80	Rockport	492	-
81	Salem	4,934	1,842
82	Saugus	2,377	60
83	Scituate	1,252	20
84	Sharon	843	53
85	Sherborn		
86	Somerville	8,577	227
87	Southborough	325	130
88	Stoneham	2,510	1,138
89	Stoughton	1,604	140
90	Stow		
91	Sudbury	1,002	105
92	Swampscott	1,307	9
93	Tewksbury	1,492	16
94	Topsfield	250	-

TABLE 4-1 (Continued). WATER USE IN 1970

No.	Community	Total volume used, gal. x 10^3	Major users, gal. x 10^3
95	Wakefield	3,305	1,060
96	Walpole	1,156	263
97	Waltham	4,233	-
98	Watertown	3,821	148
99	Wayland	1,172	130
100	Wellesley	2,281	98
101	Wenham		
102	Westborough	868	21
103	Westford	536	122
104	Weston	1,118	-
105	Westwood	974	-
106	Weymouth	3,393	768
107	Wilmington	1,906	651
108	Winchester	1,926	97
109	Winthrop	1,446	15
110	Woburn	4,096	1,063
111	Wrentham	464	-

adjusted where appropriate. The per capita values represent domestic water use and an allowance for associated commercial and nonmanufacturing industrial uses in the various communities drawing water from municipal sources.

Due to the large proportion of commercial and nonmanufacturing industrial users in Boston and Cambridge and because a large differential exists in the expected growth in service-type employment as compared to population, a

special approach was taken for these communities. For example, in the core area of EMMA, the 1960-70 period experienced a decrease in population, but an increase in total employment. Using population as the only measure of water use, therefore, would erroneously show a decreasing need for that resource during this period. In quantifying the 1970 wastewater contributions from these communities, an allowance of 70 gcd was used for domestic water consumption and 70 ged (gallons per employee per day) for commercial and nonmanufacturing industrial water use. This estimate was judged to also allow for other transient water users in those communities.

A 1-gallon increase per year was allowed for increase in per capita water use to the year 2020. For projections thereafter, implementation of conservation practices are expected to hold the per capita water use constant and no increase was allowed for. A similar allowance was made for Cambridge and Boston commercial water use. Per capita water use is shown in Table 4-2.

Sewage Flows

Sewage flows representing the dry-weather flow component excluding industrial process wastewater and infiltration are shown in Table 4-3 for 1970, 2000, 2020, and 2050.

Average Sewage Quantities. Shown in Table 4-3, these quantities were developed by multiplying the per capita water use by the sewered population and by an appropriate return ratio and a seasonal allowance. The return ratio represents the estimated proportion of water use being discharged to the sewer. Return ratios used are as follows:

1. 0.80 for areas developed to a density of 10 persons per acre or less.

2. 0.90 for areas developed to a density of 30 or greater.

3. For areas developed to a density between 10 and 30, the return ratios used were in linear proportion between the above limits.

Peak Sewage Flows. The peak sewage flows shown in Table 4-3 were computed in accordance with Figure 4-2.

TABLE 4-2
PER CAPITA WATER CONSUMPTION

COMM. NO.	COMMUNITY NAME		WATER CONSUMPTION (GCD) 1970	2000	2020	2050
1	ACTON		70.	100.	120.	120.
2	ARLINGTON	DI	100.	130.	150.	150.
3	ASHLAND	NI	75.	105.	125.	125.
4	AVON		70.	100.	120.	120.
5	BEDFORD	DI	95.	125.	145.	145.
6	BELLINGHAM		70.	100.	120.	120.
7	BELMONT	DI	70.	100.	120.	120.
8	BERLIN		70.	100.	120.	120.
9	BEVERLY		70.	100.	120.	120.
10	BILLERICA		70.	100.	120.	120.
11	BOLTON		70.	100.	120.	120.
12	BOXBOROUGH		70.	100.	120.	120.
13	BOXFORD		70.	100.	120.	120.
14	BRAINTREE	NI	70.	100.	120.	120.
15	BROOKLINE	DI	90.	120.	140.	140.
16	BROOKLINE	NI	90.	120.	140.	140.
17	BURLINGTON	DI	75.(1)	105.(1)	125.(1)	125.(1)
18	CAMBRIDGE	DI	****	****	****	****
19	CANTON	NI	95.	125.	145.	145.
20	CARLISLE		70.	100.	120.	120.
21	CHELMSFORD		95.	125.	145.	145.
22	CHELSEA	DI	70.	100.	120.	120.
23	COHASSET		80.	110.	130.	130.
24	CONCORD		75.	105.	125.	125.
25	DANVERS		90.	120.	140.	140.
26	DEDHAM	NI	90.	120.	140.	140.
27	DOVER		70.	100.	120.	120.
28	DUXBURY		95.	125.	145.	145.
29	ESSEX		70.	100.	120.	120.
30	EVERETT	DI	70.	100.	120.	120.
31	FRAMINGHAM	NI	100.	130.	150.	150.
32	FRANKLIN		75.	105.	125.	125.
33	GLOUCESTER		95.	125.	145.	145.
34	HAMILTON		70.	100.	120.	120.
35	HANOVER		70.	100.	120.	120.
36	HINGHAM	NI	70.	100.	120.	120.
37	HOLBROOK	NI	70.	100.	120.	120.
38	HOLLISTON		70.	100.	120.	120.
39	HOPKINTON		70.	100.	120.	120.
40	HUDSON		70.	100.	120.	120.
41	HULL		85.	115.	135.	135.
42	IPSWICH		90.	120.	140.	140.
43	LEXINGTON	DI	105.	135.	155.	155.
44	LINCOLN		70.	100.	120.	120.
45	LITTLETON		85.	115.	135.	135.

TABLE 4-2
PER CAPITA WATER CONSUMPTION

COMM. NO.	COMMUNITY NAME		WATER CONSUMPTION (GCD) 1970	2000	2020	2050
46	LYNN		85.	115.	135.	135.
47	LYNNFIELD		90.	120.	140.	140.
48	MALDEN	DI	85.	115.	135.	135.
49	MANCHESTER		90.	120.	140.	140.
50	MARBLEHEAD		100.	130.	150.	150.
51	MARLBOROUGH		80.	110.	130.	130.
52	MARSHFIELD		100.	130.	150.	150.
53	MAYNARD		75.	105.	125.	125.
54	MEDFIELD		70.	100.	120.	120.
55	MEDFORD	DI	95.	125.	145.	145.
56	MEDWAY		70.	100.	120.	120.
57	MELROSE	DI	70.	100.	120.	120.
58	MIDDLETON		90.	120.	140.	140.
59	MILFORD		75.	105.	125.	125.
60	MILLIS		70.	100.	120.	120.
61	MILTON	DI	75.	105.	125.	125.
62	MILTON	NI	75.	105.	125.	125.
63	NAHANT		110.	140.	160.	160.
64	NATICK	NI	110.	140.	160.	160.
65	NEEDHAM	NI	85.	115.	135.	135.
66	NEWTON	DI	75.	105.	125.	125.
67	NEWTON	NI	75.	105.	125.	125.
68	NORFOLK		85.	115.	135.	135.
69	NORTH READING		70.	100.	120.	120.
70	NORTHBOROUGH		70.	100.	120.	120.
71	NORWELL		70.	100.	120.	120.
72	NORWOOD	NI	70.	100.	120.	120.
73	PEABODY		85.	115.	135.	135.
74	PEMBROKE		70.	100.	120.	120.
75	QUINCY	NI	90.	120.	140.	140.
76	RANDOLPH	NI	70.	100.	120.	120.
77	READING	DI	70.	100.	120.	120.
78	REVERE	DI	70.	100.	120.	120.
79	ROCKLAND		70.	100.	120.	120.
80	ROCKPORT		90.	120.	140.	140.
81	SALEM		85.	115.	135.	135.
82	SAUGUS		95.	125.	145.	145.
83	SCITUATE		80.	110.	130.	130.
84	SHARON		70.	100.	120.	120.
85	SHERBORN		70.	100.	120.	120.
86	SOMERVILLE	DI	95.	125.	145.	145.
87	SOUTHBOROUGH		70.	100.	120.	120.
88	STONEHAM	DI	70.	100.	120.	120.
89	STOUGHTON	NI	70.	100.	120.	120.
90	STOW		70.	100.	120.	120.

TABLE 4-2

PER CAPITA WATER CONSUMPTION

COMM. NO.	COMMUNITY NAME		WATER CONSUMPTION (GCD) 1970	2000	2020	2050
91	SUDBURY		90.	120.	140.	140.
92	SWAMPSCOTT		95.	125.	145.	145.
93	TEWKSBURY		70.	100.	120.	120.
94	TOPSFIELD		70.	100.	120.	120.
95	WAKEFIELD	DI	90.	120.	140.	140.
96	WALPOLE	NI	70.	100.	120.	120.
97	WALTHAM	DI	70.	100.	120.	120.
98	WATERTOWN	DI	95.	125.	145.	145.
99	WAYLAND		90.	120.	140.	140.
100	WELLESLEY	NI	85.	115.	135.	135.
101	WENHAM		70.	100.	120.	120.
102	WESTBOROUGH		70.	100.	120.	120.
103	WESTFORD		70.	100.	120.	120.
104	WESTON		115.	145.	165.	165.
105	WESTWOOD	NI	80.	110.	130.	130.
106	WEYMOUTH	NI	70.	100.	120.	120.
107	WILMINGTON	DI	115.	145.	165.	165.
108	WINCHESTER	DI	80.	110.	130.	130.
109	WINTHROP	DI	70.	100.	120.	120.
110	WOBURN	DI	80.	110.	130.	130.
111	WRENTHAM		70.	100.	120.	120.
112	BOSTON PROPER	DI	****(1)	****(1)	****(1)	****(1)
113	BRIGHTON	DI	****	****	****	****
114	CHARLESTOWN	DI	****	****	****	****
115	DORCHESTER	DI	****	****	****	****
116	DORCHESTER	NI	****	****	****	****
117	EAST BOSTON	DI	****	****	****	****
118	FNWY-JMACA	DI	****	****	****	****
119	FNWY-JMACA	NI	****	****	****	****
120	HYDE PARK	NI	****	****	****	****
121	MATTAPAN	NI	****	****	****	****
122	ROSLINDALE	NI	****	****	****	****
123	ROXBURY	DI	****	****	****	****
124	SOUTH BOSTON	DI	****	****	****	****
125	WEST ROXBURY	NI	****	****	****	****

1. Due to high proportion of commercial and other nonmanufacturing water use in Cambridge and Boston, special allowance is made for these communities.

TABLE 4-3
RESIDENTIAL, COMMERCIAL, AND MINOR INDUSTRIAL
WASTEWATER FLOWS

COMM. NO.	COMMUNITY NAME		RESIDENTIAL, COMMERCIAL AND MINOR INDUSTRIAL FLOWS (MGD) 1970		2000		2020		2050	
			AVG.	PEAK	AVG.	PEAK	AVG.	PEAK	AVG.	PEAK
1	ACTON		0.00	0.00	1.57	4.80	3.92	10.59	5.52	14.12
2	ARLINGTON	DI	4.42	11.42	5.80	14.96	6.56	16.98	5.52	14.68
3	ASHLAND	NI	0.06	0.31	1.32	4.19	2.21	6.62	2.63	7.66
4	AVON		0.00	0.00	0.55	2.02	0.95	3.26	1.10	3.67
5	BEDFORD	DI	0.46	1.71	1.68	5.28	2.06	6.39	1.65	5.32
6	BELLINGHAM		0.00	0.00	1.10	3.57	1.70	5.30	2.54	7.39
7	BELMONT	DI	1.37	4.04	2.27	6.54	2.65	7.66	2.65	7.66
8	BERLIN		0.00	0.00	0.00	0.00	0.89	3.09	2.19	6.52
9	BEVERLY		1.89	5.27	4.63	11.81	6.36	15.87	6.74	16.65
10	BILLERICA		0.17	0.73	2.74	7.63	4.66	12.23	4.52	11.93
11	BOLTON		0.00	0.00	0.00	0.00	0.58	2.16	2.82	8.05
12	BOXBOROUGH		0.00	0.00	0.00	0.00	0.89	3.08	2.18	6.50
13	BOXFORD		0.00	0.00	0.00	0.00	1.11	3.70	2.84	8.09
14	BRAINTREE	NI	1.92	5.34	3.80	10.02	5.01	13.00	5.26	13.54
15	BROOKLINE	DI	2.44	6.92	3.38	9.53	3.69	10.50	3.42	9.85
16	BROOKLINE	NI	1.99	5.75	3.23	9.03	3.80	10.62	3.56	10.06
17	BURLINGTON	DI	0.64	2.17	2.77	7.76	3.23	9.08	2.46	7.23
18	CAMBRIDGE	DI	9.64	22.44	14.67	33.78	16.70	38.65	14.35	33.93
19	CANTON	NI	0.67	2.35	3.29	9.21	4.97	13.33	5.96	15.50
20	CARLISLE		0.00	0.00	0.00	0.00	0.88	3.05	2.35	6.92
21	CHELMSFORD		0.00	0.00	2.89	8.28	5.96	15.50	6.23	16.09
22	CHELSEA	DI	1.86	5.27	1.71	5.19	1.86	5.73	1.97	6.01
23	COHASSET		0.02	0.11	0.73	2.59	1.57	5.01	1.74	5.47
24	CONCORD		0.38	1.42	1.85	5.54	3.94	10.71	5.66	14.49
25	DANVERS		1.45	4.41	3.23	9.01	4.39	11.93	3.89	10.80
26	DEDHAM	NI	1.71	5.05	2.80	8.00	3.34	9.51	2.70	7.96
27	DOVER		0.00	0.00	0.00	0.00	0.42	1.67	1.21	3.97
28	DUXBURY		0.00	0.00	0.00	0.00	0.53	2.07	1.55	5.05
29	ESSEX		0.00	0.00	0.24	1.00	0.89	3.07	1.55	4.89
30	EVERETT	DI	2.60	6.98	3.04	8.42	3.22	9.08	2.69	7.79
31	FRAMINGHAM	NI	4.04	10.55	8.78	21.03	11.01	26.01	10.84	25.67
32	FRANKLIN		0.49	1.75	1.91	5.69	3.71	10.20	5.21	13.51
33	GLOUCESTER		1.43	4.49	3.18	9.01	4.69	12.78	5.16	13.84
34	HAMILTON		0.00	0.00	0.54	1.98	1.64	5.13	2.56	7.44
35	HANOVER		0.00	0.00	1.33	4.18	2.24	6.64	2.89	8.22
36	HINGHAM	NI	0.21	0.84	1.54	4.72	2.99	8.46	3.09	8.68
37	HOLBROOK	NI	0.00	0.00	1.06	3.46	1.50	4.76	2.46	7.19
38	HOLLISTON		0.00	0.00	0.80	2.75	2.21	6.58	3.17	8.87
39	HOPKINTON		0.00	0.00	0.72	2.50	2.22	6.60	3.89	10.52
40	HUDSON		0.69	2.28	2.01	5.89	2.90	8.25	3.00	8.48
41	HULL		0.35	1.43	0.69	2.48	0.79	2.85	0.89	3.13
42	IPSWICH		0.33	1.30	1.55	4.90	2.53	7.54	3.32	9.47
43	LEXINGTON	DI	2.06	6.06	4.23	11.50	6.42	16.68	6.88	17.67

TABLE 4-3
RESIDENTIAL, COMMERCIAL, AND MINOR INDUSTRIAL
WASTEWATER FLOWS

COMM. NO.	COMMUNITY NAME		RESIDENTIAL, COMMERCIAL AND MINOR INDUSTRIAL FLOWS (MGD) 1970 AVG.	1970 PEAK	2000 AVG.	2000 PEAK	2020 AVG.	2020 PEAK	2050 AVG.	2050 PEAK
44	LINCOLN		0.00	0.00	0.44	1.68	1.06	3.58	2.63	7.59
45	LITTLETON		0.00	0.00	0.51	1.93	1.97	6.09	3.46	9.75
46	LYNN		6.35	15.07	8.01	19.21	9.02	21.78	8.22	20.13
47	LYNNFIELD		0.00	0.00	1.20	3.94	2.04	6.31	2.58	7.67
48	MALDEN	DI	4.00	10.25	4.87	12.70	5.37	14.14	4.33	11.78
49	MANCHESTER		0.25	1.05	1.02	3.46	1.78	5.62	1.93	6.04
50	MARBLEHEAD		1.66	5.05	2.16	6.54	2.39	7.27	2.27	6.98
51	MARLBOROUGH		1.07	3.35	2.72	7.71	4.53	12.11	4.89	12.90
52	MARSHFIELD		0.03	0.15	2.54	7.48	4.43	12.18	5.46	14.50
53	MAYNARD		0.52	1.83	0.95	3.19	1.29	4.22	1.17	3.91
54	MEDFIELD		0.08	0.39	1.27	4.05	2.33	6.89	3.13	8.80
55	MEDFORD	DI	5.11	12.82	7.13	17.74	8.00	20.00	7.24	18.38
56	MEDWAY		0.01	0.09	0.61	2.18	1.49	4.74	2.13	6.38
57	MELROSE	DI	1.91	5.34	3.16	8.64	3.89	10.60	3.73	10.22
58	MIDDLETON		0.00	0.00	0.23	0.99	0.81	2.94	1.61	5.17
59	MILFORD		1.06	3.30	1.86	5.57	2.63	7.65	2.88	8.26
60	MILLIS		0.08	0.38	0.89	2.99	1.85	5.67	2.62	7.56
61	MILTON	DI	0.30	1.17	0.44	1.70	0.53	2.03	0.57	2.16
62	MILTON	NI	1.24	3.75	2.62	7.40	3.76	10.31	3.88	10.58
63	NAHANT		0.36	1.45	0.43	1.72	0.47	1.90	0.60	2.33
64	NATICK	NI	1.88	5.66	4.19	11.49	5.92	15.67	5.68	15.13
65	NEEDHAM	NI	1.73	5.07	4.05	10.82	5.75	14.88	6.50	16.48
66	NEWTON	DI	2.46	6.65	4.13	10.84	5.06	13.21	5.00	13.09
67	NEWTON	NI	2.99	7.83	4.78	12.22	6.09	15.39	6.23	15.69
68	NORFOLK		0.00	0.00	0.00	0.00	0.66	2.44	1.80	5.65
69	NORTH READING		0.00	0.00	1.04	3.42	1.91	5.82	2.49	7.26
70	NORTHBOROUGH		0.00	0.00	1.19	3.80	2.40	7.05	3.78	10.31
71	NORWELL		0.00	0.00	0.53	1.95	1.02	3.45	2.71	7.78
72	NORWOOD	NI	1.71	4.84	3.06	8.36	3.77	10.27	3.34	9.27
73	PEABODY		2.03	5.78	5.14	13.19	6.09	15.60	5.46	14.24
74	PEMBROKE		0.00	0.00	0.59	2.13	1.00	3.40	2.25	6.66
75	QUINCY	NI	6.51	15.48	10.27	23.80	13.05	29.85	11.98	27.77
76	RANDOLPH	NI	0.75	2.45	2.46	6.97	3.00	8.48	2.77	7.93
77	READING	DI	0.75	2.45	2.32	6.63	3.29	9.15	3.95	10.68
78	REVERE	DI	2.39	6.46	3.94	10.43	4.52	12.03	4.19	11.30
79	ROCKLAND		0.17	0.72	0.77	2.66	1.74	5.39	1.59	4.99
80	ROCKPORT		0.29	1.21	0.91	3.16	1.50	4.88	1.94	6.06
81	SALEM		2.74	7.47	3.58	9.80	3.94	10.89	3.14	9.00
[illegible]	SAUGUS		1.07	3.46	2.46	7.23	3.16	9.14	2.96	8.67
83	SCITUATE		0.12	0.59	1.33	4.24	2.57	7.55	3.16	8.96
84	SHARON		0.00	0.00	0.85	2.89	2.35	6.91	3.76	10.22
85	SHERBORN		0.00	0.00	0.00	0.00	0.53	2.02	1.33	4.32
86	SOMERVILLE	DI	7.54	17.92	7.48	18.52	8.61	21.34	8.53	21.17

TABLE 4-3
RESIDENTIAL, COMMERCIAL, AND MINOR INDUSTRIAL
WASTEWATER FLOWS

COMM. NO.	COMMUNITY NAME		RESIDENTIAL, COMMERCIAL AND MINOR INDUSTRIAL FLOWS (MGD) 1970 AVG.	1970 PEAK	2000 AVG.	2000 PEAK	2020 AVG.	2020 PEAK	2050 AVG.	2050 PEAK
87	SOUTHBOROUGH		0.00	0.00	0.57	2.08	1.50	4.75	2.82	8.07
88	STONEHAM	DI	1.10	3.36	1.71	5.15	1.91	5.83	2.03	6.13
89	STOUGHTON	NI	0.31	1.18	2.62	7.35	4.03	10.83	4.32	11.48
90	STOW		0.00	0.00	0.00	0.00	0.46	1.77	1.36	4.39
91	SUDBURY		0.00	0.00	1.99	6.03	5.08	13.49	6.95	17.51
92	SWAMPSCOTT		0.97	3.19	1.75	5.46	2.15	6.65	2.38	7.25
93	TEWKSBURY		0.00	0.00	2.06	6.01	3.28	9.13	3.77	10.25
94	TOPSFIELD		0.00	0.00	0.37	1.45	1.38	4.43	2.17	6.48
95	WAKEFIELD	DI	1.60	4.80	3.48	9.61	4.53	12.30	5.13	13.64
96	WALPOLE	NI	0.32	1.21	2.40	6.83	4.28	11.41	5.20	13.40
97	WALTHAM	DI	2.59	6.86	6.96	16.66	8.34	19.97	7.79	18.84
98	WATERTOWN	DI	3.09	8.41	3.23	9.11	3.61	10.25	3.51	10.00
99	WAYLAND		0.00	0.00	1.62	5.09	4.10	11.28	5.12	13.59
100	WELLESLEY	NI	1.54	4.59	2.91	8.20	3.53	9.89	3.12	8.94
101	WENHAM		0.00	0.00	0.00	0.00	0.47	1.82	1.20	3.96
102	WESTBOROUGH		0.21	0.84	1.24	3.95	2.52	7.34	3.35	9.29
103	WESTFORD		0.00	0.00	0.53	1.94	1.72	5.33	4.29	11.43
104	WESTON		0.00	0.00	1.99	6.22	3.43	10.00	3.22	9.47
105	WESTWOOD	NI	0.27	1.08	2.01	6.00	2.86	8.27	3.08	8.79
106	WEYMOUTH	NI	1.55	4.48	4.61	11.77	5.87	14.84	5.85	14.79
107	WILMINGTON	DI	0.00	0.00	3.15	9.10	4.88	13.41	5.09	13.90
108	WINCHESTER	DI	1.42	4.24	2.21	6.47	2.46	7.29	2.27	6.81
109	WINTHROP	DI	1.23	3.74	1.20	3.87	1.19	3.93	1.35	4.39
110	WOBURN	DI	1.79	5.17	4.48	11.71	5.44	14.13	4.73	12.57
111	WRENTHAM		0.00	0.00	0.57	2.08	1.91	5.81	3.65	9.99
112	BOSTON PROPER	DI	23.05	57.32	36.38	86.72	46.51	104.88	51.57	108.77
113	BRIGHTON	DI	4.98	12.50	5.92	15.28	6.48	16.98	5.16	14.15
114	CHARLESTOWN	DI	1.69	5.38	1.80	6.06	2.03	6.96	1.82	6.55
115	DORCHESTER	DI	8.41	19.22	12.79	28.85	17.21	37.92	14.48	32.98
116	DORCHESTER	NI	1.72	5.03	1.34	4.34	1.64	5.39	1.34	4.64
117	EAST BOSTON	DI	2.90	7.92	2.99	8.55	3.29	9.53	2.94	8.74
118	FNWY-JMACA	DI	2.63	7.19	2.32	6.93	2.70	8.15	2.72	8.29
119	FNWY-JMACA	NI	0.67	2.30	0.64	2.37	0.72	2.75	0.73	2.85
120	HYDE PARK	NI	2.45	6.70	3.81	10.38	3.95	10.97	3.01	8.84
121	MATTAPAN	NI	2.46	6.75	3.27	9.06	3.44	9.73	3.01	8.68
122	ROSLINDALE	NI	1.74	5.01	4.20	11.31	5.17	13.76	7.95	19.80
123	ROXBURY	DI	11.19	26.13	10.99	27.98	12.20	31.44	12.20	31.65
124	SOUTH BOSTON	DI	4.38	11.73	4.67	13.25	4.86	14.18	4.66	13.83
125	WEST ROXBURY	NI	1.60	4.69	2.17	6.42	2.59	7.67	2.37	7.14

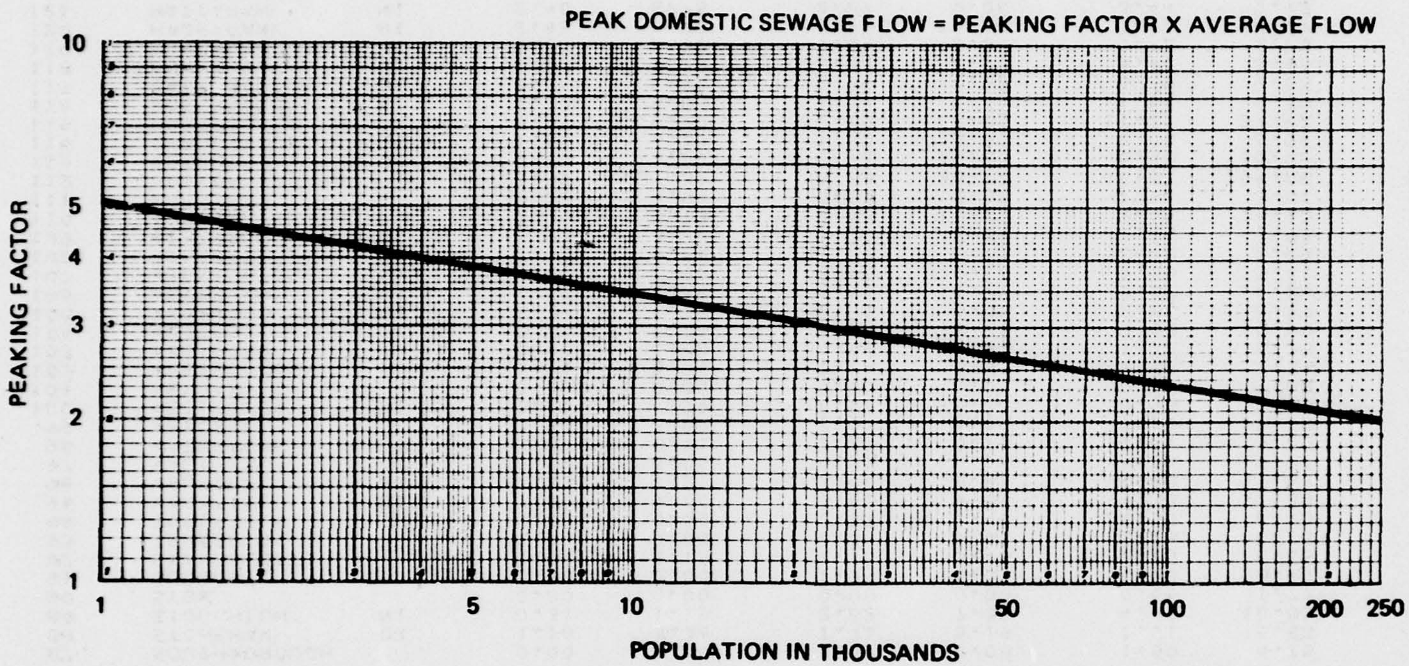


FIG. 4-1 PEAKING FACTOR FOR DOMESTIC SEWAGE FLOWS

<u>Composition of Sewage</u>. The two major constituents considered important to the sizing and cost of treatment of the MDC system flows are BOD (biochemical oxygen demand and SS (suspended solids). An allowance of 200 mg/L (milligrams per liter) was made for both components in sewage flow. Allowances for industries were made separately in the next chapter and infiltration is assumed to be carrying no pollution.

CHAPTER 5
INDUSTRIAL PROCESS WASTEWATER ALLOWANCES

General

In estimating future dry-weather flows, the most difficult component to determine is the contribution by industries discharging process wastewaters. Normally, there are few records establishing such quantities. In addition, a reliable basis is not available for predicting the degree of impact on industrial process wastewater quantities by such factors as increasing costs and more stringent wastewater disposal regulations, except to acknowledge that all cause a decrease in wastewater production.

The purposes for separating the industrial component from total dry-weather flow in making projections were: (1) because in the EMMA area, future growth in industrial manufacturing activity is not expected to parallel population growth; (2) because water use from municipal systems usually does not completely include industrial sources; and (3) because new Federal regulations require recovery of costs from industries in an explicitly prescribed way requiring separating out the industrial waste component (see Technical Data Vol. 3, Industrial Process Wastewater Analysis and Regulation).

During the initial stages of the study, the source of industrial wastewater data was an evaluation of readily available information as a basis for estimating flows. Later on, this data was modified when more detailed results were made available for an industrial wastes survey of major industries. The information presented here is the final data obtained as a result of the inventory of major industries.

Flow Quantification Procedure

Projections of economic activity, as presented in Technical Data Vol. 1, were made in terms of employment. Five categories of employment were projected as shown in Table 5-1.

A study of the quantity of wastes produced by each SIC (Standard Industrial Classification) was made resulting in the following SIC groupings shown in Table 5-2.

TABLE 5-1. DESCRIPTION OF ECONOMIC ACTIVITY CATEGORIES

Category	Description
I-1	Dry manufacturing - little or no process water use.
I-2	Wet manufacturing - moderate levels of process water use.
I-3	Wet manufacturing - heavy use of process water.
I-4	Industrial nonmanufacturing - includes agriculture, mining, construction, transportation, communications, utilities, and wholesale trade.
I-5	Commercial - includes retail trade; finance, insurance and real estate; services, and government.

TABLE 5-2. STANDARD INDUSTRIAL CLASSIFICATION GROUPS

Category	SIC codes included
I-1	19, 205, 21, 227, 228, 23, 24, 25, 27, 301, 302, 31 (except 311), 32 (except 324, 329), 332, 334, 339, 34 (except 347), 35, 36, 37, (except 372, 373), 38, 39 (except 394)
I-2	20 (except 205, 206), 22 (except 227, 228), 264, 265, 266, 267, 28, 29 (except 291), 30 (except 301, 302), 311, 324, 329, 331, 335, 336, 347, 372, 373, 394
I-3	206, 261, 262, 263, 291
I-4	01-17, 40-50
I-5	52-94

The first three categories represent manufacturing process wastes contributions and are discussed in this chapter. The latter two categories were included in quantifying sewage flows in Chapter 4.

The overall procedure finally used was to survey major industries to determine their present wastewater discharges and to estimate the remaining contributions from minor industries on the basis of wastewater allowances related to the remaining employment in each community not accounted for by the major industries.

Since it is not possible to designate the economic activity projections to each firm and since industrial cost recovery is generally allocated to actual facilities used, major industry contributions as inventoried are held constant with time.

Projections in wastewater production by growth of existing firms and creation of new industries is represented in the projections referred to as the industrial flows and are related directly to changes in employment.

Major Industry Flows

A survey was conducted of industries judged to be potential dischargers of about 50,000 gpd (gallons per day) or more process wastewater. The industries included were based on the following criteria as shown in Table 5-3 and were selected from industrial directories.

TABLE 5-3. INDUSTRIAL CATEGORIES SURVEYED

Category	Minimum employment necessary to be surveyed
I-1	250
I-2	100
I-3	All industries included

Utilizing this criteria, a list of 375 industries was established and questionnaires were sent to each. As a result of these questionnaires and from information derived from site visits to selected industries (about 214) and other sources, a final list of about 180 industries was established as being in the major category which is composed of the 101 industries from the industrial wastes survey plus 79 obtained from other sources.

In addition to these, certain major institutions were included as major point sources in the quantification procedure in order to account for their wastes contributions in sizing of facilities needed.

Table 5-4 shows by community these major industry and point source contributions, including major institutional contributions.

Other Industrial Flows

For the manufacturing employment not accounted for by the major industries, general allowances were made for purposes of sizing of facilities and estimating costs.

Existing employment under this category represents the smaller industries about which activities are generally not readily quantifiable. Projected employment represents the smaller industries, new developments and growth of the large industries.

Using manufacturing employment as a measure of process wastewater contributions, the previously identified manufacturing industrial groupings (I-1, I-2, and I-3) were studied on a sample basis to determine allowances for wastewaters. Table 5-5 shows the resulting criteria selected for estimating average process wastewater contributions from these industrial groupings. Table 5-6 shows the flows developed for each community.

TABLE 5-5. MANUFACTURING PROCESS WASTEWATER ALLOWANCE CRITERIA

Category	Description	Process wastewater allowance, ged
I-1	Dry manufacturing	170
I-2	Wet manufacturing	700
I-3	Very wet manufacturing	2,000

Peak Flows

Unless detailed studies are made for each industry, peak process waste discharges cannot be estimated reliably. For industries, peak flows depend upon such factors as

TABLE 5-4
INDUSTRIAL FLOWS FROM MAJOR INDUSTRIES
SERVED BY PUBLIC SEWERS

COMM. NO.	COMMUNITY NAME		FLOWS FROM MAJOR INDUSTRIES SERVED BY PUBLIC SEWER (MGD) 1970 AVG.	1970 PEAK	2000 AVG.	2000 PEAK	2020 AVG.	2020 PEAK	2050 AVG.	2050 PEAK
1	ACTON		0.00	[illegible]	0.40	1.40	0.40	1.40	0.40	1.40
2	ARLINGTON	DI	0.07	0.24	0.07	0.24	0.07	0.24	0.07	0.24
3	ASHLAND	NI	0.75	2.62	0.75	2.62	0.75	2.62	0.75	2.62
4	AVON		0.00	0.00	0.07	0.24	0.07	0.24	0.07	0.24
5	BEDFORD	DI	0.29	1.01	0.29	1.01	0.29	1.01	0.29	1.01
6	BELLINGHAM		0.00	0.00	0.06	0.21	0.06	0.21	0.06	0.21
7	BELMONT	DI	0.11	0.38	0.11	0.38	0.11	0.38	0.11	0.38
8	BERLIN		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
9	BEVERLY		0.30	1.04	0.30	1.04	0.30	1.04	0.30	1.04
10	BILLERICA		0.38	1.33	0.38	1.33	0.38	1.33	0.38	1.33
11	BOLTON		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
12	BOXBOROUGH		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
13	BOXFORD		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
14	BRAINTREE	NI	0.06	0.21	0.06	0.21	0.06	0.21	0.06	0.21
15	BROOKLINE	DI	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
16	BROOKLINE	NI	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
17	BURLINGTON	DI	0.25	0.87	0.25	0.87	0.25	0.87	0.25	0.87
18	CAMBRIDGE	DI	3.07	10.74	3.07	10.74	3.07	10.74	3.07	10.74
19	CANTON	NI	0.30	1.04	0.30	1.04	0.30	1.04	0.30	1.04
20	CARLISLE		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
21	CHELMSFORD		0.00	0.00	0.19	0.66	0.19	0.66	0.19	0.66
22	CHELSEA	DI	0.41	1.43	0.41	1.43	0.41	1.43	0.41	1.43
23	COHASSET		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
24	CONCORD		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
25	DANVERS		0.53	1.85	0.53	1.85	0.53	1.85	0.53	1.85
26	DEDHAM	NI	0.26	0.91	0.26	0.91	0.26	0.91	0.26	0.91
27	DOVER		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
28	DUXBURY		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
29	ESSEX		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
30	EVERETT	DI	2.21	7.73	2.21	7.73	2.21	7.73	2.21	7.73
31	FRAMINGHAM	NI	0.74	2.58	0.74	2.58	0.74	2.58	0.74	2.58
32	FRANKLIN		0.41	1.43	0.41	1.43	0.41	1.43	0.41	1.43
33	GLOUCESTER		0.16	0.56	0.16	0.56	0.16	0.56	0.16	0.56
34	HAMILTON		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
35	HANOVER		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
36	HINGHAM	NI	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
37	HOLBROOK	NI	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
38	HOLLISTON		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
39	HOPKINTON		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
40	HUDSON		0.11	0.38	0.11	0.38	0.11	0.38	0.11	0.38
41	HULL		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
42	IPSWICH		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
43	LEXINGTON	DI	0.20	0.70	0.20	0.70	0.20	0.70	0.20	0.70

TABLE 5-4
INDUSTRIAL FLOWS FROM MAJOR INDUSTRIES
SERVED BY PUBLIC SEWERS

COMM. NO.	COMMUNITY NAME		FLOWS FROM MAJOR INDUSTRIES SERVED BY PUBLIC SEWER (MGD) 1970 AVG.	1970 PEAK	2000 AVG.	2000 PEAK	2020 AVG.	2020 PEAK	2050 AVG.	2050 PEAK
44	LINCOLN		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
45	LITTLETON		0.00	0.00	0.12	0.42	0.12	0.42	0.12	0.42
46	LYNN		3.56	12.46	3.56	12.46	3.56	12.46	3.56	12.46
47	LYNNFIELD		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
48	MALDEN	DI	0.32	1.12	0.32	1.12	0.32	1.12	0.32	1.12
49	MANCHESTER		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
50	MARBLEHEAD		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
51	MARLBOROUGH		0.07	0.24	0.07	0.24	0.07	0.24	0.07	0.24
52	MARSHFIELD		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
53	MAYNARD		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
54	MEDFIELD		0.09	0.31	0.09	0.31	0.09	0.31	0.09	0.31
55	MEDFORD	DI	0.18	0.62	0.18	0.62	0.18	0.62	0.18	0.62
56	MEDWAY		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
57	MELROSE	DI	0.15	0.52	0.15	0.52	0.15	0.52	0.15	0.52
58	MIDDLETON		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
59	MILFORD		0.05	0.17	0.05	0.17	0.05	0.17	0.05	0.17
60	MILLIS		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
61	MILTON	DI	0.08	0.28	0.08	0.28	0.08	0.28	0.08	0.28
62	MILTON	NI	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
63	NAHANT		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
64	NATICK	NI	1.81	6.33	1.81	6.33	1.81	6.33	1.81	6.33
65	NEEDHAM	NI	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
66	NEWTON	DI	0.33	1.15	0.33	1.15	0.33	1.15	0.33	1.15
67	NEWTON	NI	0.44	1.54	0.44	1.54	0.44	1.54	0.44	1.54
68	NORFOLK		0.00	0.00	0.00	0.00	0.73	2.55	0.73	2.55
69	NORTH READING		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
70	NORTHBOROUGH		0.00	0.00	0.05	0.17	0.05	0.17	0.05	0.17
71	NORWELL		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
72	NORWOOD	NI	0.79	2.76	0.79	2.76	0.79	2.76	0.79	2.76
73	PEABODY		4.18	4.78	4.18	4.78	4.18	4.78	4.18	4.78
74	PEMBROKE		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
75	QUINCY	NI	0.64	2.24	0.64	2.24	0.64	2.24	0.64	2.24
76	RANDOLPH	NI	0.10	0.35	0.10	0.35	0.10	0.35	0.10	0.35
77	READING	DI	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
78	REVERE	DI	0.13	0.45	0.13	0.45	0.13	0.45	0.13	0.45
79	ROCKLAND		0.33	1.15	0.33	1.15	0.33	1.15	0.33	1.15
80	ROCKPORT		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
81	SALEM		1.25	4.37	1.25	4.37	1.25	4.37	1.25	4.37
82	SAUGUS		0.10	0.35	0.10	0.35	0.10	0.35	0.10	0.35
83	SCITUATE		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
84	SHARON		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
85	SHERBORN		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
86	SOMERVILLE	DI	0.58	2.03	0.58	2.03	0.58	2.03	0.58	2.03

TABLE 5-4
INDUSTRIAL FLOWS FROM MAJOR INDUSTRIES
SERVED BY PUBLIC SEWERS

COMM. NO.	COMMUNITY NAME		FLOWS FROM MAJOR INDUSTRIES SERVED BY PUBLIC SEWER (MGD) 1970 AVG.	1970 PEAK	2000 AVG.	2000 PEAK	2020 AVG.	2020 PEAK	2050 AVG.	2050 PEAK
87	SOUTHBOROUGH		0.00	0.00	0.08	0.28	0.08	0.28	0.08	0.28
88	STONEHAM	DI	0.11	0.38	0.11	0.38	0.11	0.38	0.11	0.38
89	STOUGHTON	NI	0.26	0.91	0.26	0.91	0.26	0.91	0.26	0.91
90	STOW		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
91	SUDBURY		0.00	0.00	0.06	0.21	0.06	0.21	0.06	0.21
92	SWAMPSCOTT		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
93	TEWKSBURY		0.00	0.00	1.30	4.55	1.30	4.55	1.30	4.55
94	TOPSFIELD		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
95	WAKEFIELD	DI	1.41	4.93	1.41	4.93	1.41	4.93	1.41	4.93
96	WALPOLE	NI	4.51	15.78	4.51	15.78	4.51	15.78	4.51	15.78
97	WALTHAM	DI	4.85	16.97	4.85	16.97	4.85	16.97	4.85	16.97
98	WATERTOWN	DI	0.35	1.22	0.35	1.22	0.35	1.22	0.35	1.22
99	WAYLAND		0.00	0.00	0.17	0.59	0.17	0.59	0.17	0.59
100	WELLESLEY	NI	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
101	WENHAM		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
102	WESTBOROUGH		0.12	0.42	0.12	0.42	0.12	0.42	0.12	0.42
103	WESTFORD		0.00	0.00	0.10	0.35	0.10	0.35	0.10	0.35
104	WESTON		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
105	WESTWOOD	NI	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
106	WEYMOUTH	NI	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
107	WILMINGTON	DI	0.00	0.00	0.43	1.50	0.43	1.50	0.43	1.50
108	WINCHESTER	DI	0.71	2.48	0.71	2.48	0.71	2.48	0.71	2.48
109	WINTHROP	DI	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
110	WOBURN	DI	2.62	9.17	2.62	9.17	2.62	9.17	2.62	9.17
111	WRENTHAM		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
112	BOSTON PROPER	DI	4.03	14.10	4.03	14.10	4.03	14.10	4.03	14.10
113	BRIGHTON	DI	0.96	3.36	0.96	3.36	0.96	3.36	0.96	3.36
114	CHARLESTOWN	DI	1.20	4.19	1.20	4.19	1.20	4.19	1.20	4.19
115	DORCHESTER	DI	1.55	5.42	1.55	5.42	1.55	5.42	1.55	5.42
116	DORCHESTER	NI	0.80	2.80	0.80	2.80	0.80	2.80	0.80	2.80
117	EAST BOSTON	DI	0.44	1.54	0.44	1.54	0.44	1.54	0.44	1.54
118	FNWY-JMACA	DI	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
119	FNWY-JMACA	NI	0.06	0.21	0.06	0.21	0.06	0.21	0.06	0.21
120	HYDE PARK	NI	4.26	14.91	4.26	14.91	4.26	14.91	4.26	14.91
121	MATTAPAN	NI	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
122	ROSLINDALE	NI	0.12	0.42	0.12	0.42	0.12	0.42	0.12	0.42
123	ROXBURY	DI	2.46	8.60	2.46	8.60	2.46	8.60	2.46	8.60
124	SOUTH BOSTON	DI	3.35	11.72	3.35	11.72	3.35	11.72	3.35	11.72
125	WEST ROXBURY	NI	0.07	0.24	0.07	0.24	0.07	0.24	0.07	0.24

TABLE 5-6
OTHER INDUSTRIAL FLOWS

COMM. NO.	COMMUNITY NAME		1970 AVG.	1970 PEAK	2000 AVG.	2000 PEAK	2020 AVG.	2020 PEAK	2050 AVG.	2050 PEAK
			OTHER INDUSTRIAL FLOWS (MGD)							
1	ACTON		0.00	0.00	0.24	0.84	0.28	0.99	0.30	1.07
2	ARLINGTON	DI	0.12	0.43	0.11	0.40	0.08	0.29	0.07	0.25
3	ASHLAND	NI	0.07	0.27	0.24	0.85	0.23	0.83	0.22	0.78
4	AVON		0.00	0.00	0.15	0.55	0.15	0.53	0.09	0.34
5	BEDFORD	DI	0.46	1.63	0.63	2.21	0.65	2.27	0.58	2.05
6	BELLINGHAM		0.00	0.00	0.10	0.36	0.11	0.39	0.19	0.67
7	BELMONT	DI	0.07	0.26	0.04	0.14	0.02	0.09	0.00	0.03
8	BERLIN		0.00	0.00	0.00	0.00	0.09	0.33	0.09	0.34
9	BEVERLY		0.28	0.99	0.39	1.39	0.35	1.25	0.14	0.50
10	BILLERICA		0.25	0.89	0.37	1.31	0.38	1.34	0.27	0.96
11	BOLTON		0.00	0.00	0.00	0.00	0.14	0.51	0.23	0.81
12	BOXBOROUGH		0.00	0.00	0.00	0.00	0.02	0.09	0.07	0.27
13	BOXFORD		0.00	0.00	0.00	0.00	0.16	0.58	0.22	0.79
14	BRAINTREE	NI	0.84	2.95	0.65	2.27	0.41	1.45	0.10	0.37
15	BROOKLINE	DI	0.06	0.21	0.01	0.06	0.00	0.00	0.03	0.11
16	BROOKLINE	NI	0.01	0.05	0.00	0.00	0.00	0.00	0.03	0.11
17	BURLINGTON	DI	0.37	1.30	0.35	1.25	0.36	1.26	0.32	1.14
18	CAMBRIDGE	DI	4.75	16.64	1.42	4.99	1.02	3.57	1.14	4.00
19	CANTON	NI	1.33	4.66	1.08	3.79	0.70	2.45	0.08	0.29
20	CARLISLE		0.00	0.00	0.00	0.00	0.13	0.47	0.09	0.34
21	CHELMSFORD		0.00	0.00	0.16	0.58	0.19	0.68	0.18	0.65
22	CHELSEA	DI	0.52	1.82	0.09	0.32	0.02	0.08	0.06	0.23
23	COHASSET		0.03	0.10	0.03	0.13	0.01	0.03	0.04	0.14
24	CONCORD		0.24	0.87	0.41	1.46	0.40	1.42	0.48	1.68
25	DANVERS		0.69	2.41	0.68	2.40	0.61	2.15	0.51	1.81
26	DEDHAM	NI	0.34	1.19	0.28	0.99	0.24	0.85	0.14	0.51
27	DOVER		0.00	0.00	0.00	0.00	0.00	0.00	0.07	0.24
28	DUXBURY.		0.00	0.00	0.00	0.00	0.07	0.27	0.18	0.63
29	ESSEX		0.00	0.00	0.06	0.22	0.07	0.26	0.07	0.25
30	EVERETT	DI	0.39	1.38	0.15	0.55	0.13	0.47	0.13	0.47
31	FRAMINGHAM	NI	1.57	5.52	0.73	2.58	0.31	1.09	0.31	1.09
32	FRANKLIN		0.27	0.95	0.33	1.18	0.33	1.18	0.38	1.33
33	GLOUCESTER		1.00	3.50	0.80	2.82	0.74	2.59	0.36	1.27
34	HAMILTON		0.00	0.00	0.11	0.41	0.12	0.44	0.20	0.73
35	HANOVER		0.00	0.00	0.26	0.92	0.27	0.95	0.22	0.77
36	HINGHAM	NI	0.21	0.74	0.33	1.17	0.32	1.14	0.28	0.99
37	HOLBROOK	NI	0.00	0.00	0.19	0.68	0.20	0.70	0.11	0.41
38	HOLLISTON		0.00	0.00	0.27	0.96	0.27	0.94	0.22	0.78
39	HOPKINTON		0.00	0.00	0.13	0.47	0.15	0.55	0.16	0.59
40	HUDSON		0.45	1.60	0.54	1.90	0.47	1.66	0.24	0.85
41	HULL		0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.11
42	IPSWICH		0.23	0.81	0.28	1.00	0.32	1.15	0.31	1.09
43	LEXINGTON	DI	0.11	0.41	0.20	0.70	0.05	0.20	0.00	0.00
44	LINCOLN		0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00

TABLE 5-6
OTHER INDUSTRIAL FLOWS

COMM. NO.	COMMUNITY NAME		OTHER INDUSTRIAL FLOWS (MGD) 1970 AVG.	1970 PEAK	2000 AVG.	2000 PEAK	2020 AVG.	2020 PEAK	2050 AVG.	2050 PEAK
45	LITTLETON		0.00	0.00	0.17	0.62	0.18	0.66	0.16	0.57
46	LYNN		1.82	6.37	1.30	4.58	1.03	3.62	0.60	2.11
47	LYNNFIELD		0.00	0.00	0.11	0.39	0.08	0.29	0.08	0.29
48	MALDEN	DI	2.11	7.38	1.24	4.36	0.97	3.41	0.51	1.80
49	MANCHESTER		0.02	0.07	0.12	0.42	0.09	0.33	0.03	0.11
50	MARBLEHEAD		0.29	1.04	0.34	1.19	0.30	1.05	0.20	0.71
51	MARLBOROUGH		0.51	1.81	0.69	2.42	0.72	2.52	0.73	2.57
52	MARSHFIELD		0.01	0.06	0.04	0.14	0.05	0.20	0.08	0.28
53	MAYNARD		0.76	2.69	0.47	1.67	0.45	1.59	0.38	1.36
54	MEDFIELD		0.04	0.15	0.19	0.66	0.20	0.71	0.19	0.69
55	MEDFORD	DI	0.58	2.04	0.50	1.75	0.42	1.48	0.23	0.83
56	MEDWAY		0.07	0.25	0.13	0.47	0.17	0.62	0.15	0.53
57	MELROSE	DI	0.31	1.11	0.16	0.58	0.08	0.29	0.04	0.14
58	MIDDLETON		0.00	0.00	0.24	0.86	0.17	0.62	0.16	0.58
59	MILFORD		0.33	1.17	0.40	1.42	0.42	1.47	0.36	1.29
60	MILLIS		0.31	1.11	0.37	1.31	0.37	1.29	0.23	0.80
61	MILTON	DI	0.00	0.01	0.17	0.60	0.10	0.35	0.03	0.11
62	MILTON	NI	0.09	0.31	0.00	0.00	0.00	0.00	0.00	0.00
63	NAHANT		0.00	0.00	0.34	1.19	0.26	0.92	0.13	0.48
64	NATICK	NI	0.86	3.01	0.43	1.52	0.38	1.34	0.31	1.08
65	NEEDHAM	NI	1.01	3.56	0.66	2.31	0.45	1.58	0.14	0.51
66	NEWTON	DI	1.06	3.71	0.35	1.24	0.08	0.30	0.03	0.11
67	NEWTON	NI	0.87	3.06	0.38	1.34	0.00	0.00	0.00	0.00
68	NORFOLK		0.00	0.00	0.00	0.00	0.08	0.31	0.04	0.14
69	NORTH READING		0.00	0.00	0.14	0.50	0.16	0.56	0.15	0.54
70	NORTHBOROUGH		0.00	0.00	0.23	0.82	0.26	0.94	0.27	0.97
71	NORWELL		0.00	0.00	0.07	0.26	0.08	0.29	0.27	0.96
72	NORWOOD	NI	0.79	2.79	0.57	2.01	0.50	1.75	0.08	0.30
73	PEABODY		1.94	2.54	1.25	1.64	0.68	0.89	0.02	0.02
74	PEMBROKE		0.00	0.00	0.11	0.40	0.11	0.40	0.30	1.07
75	QUINCY	NI	2.45	8.58	1.69	5.94	1.35	4.74	0.43	1.52
76	RANDOLPH	NI	0.49	1.72	0.46	1.62	0.33	1.17	0.22	0.78
77	READING	DI	0.39	1.38	0.35	1.23	0.23	0.82	0.04	0.14
78	REVERE	DI	0.15	0.52	0.18	0.64	0.17	0.60	0.12	0.44
79	ROCKLAND		0.39	1.39	0.33	1.15	0.27	0.96	0.25	0.88
80	ROCKPORT		0.03	0.13	0.06	0.23	0.06	0.24	0.09	0.31
81	SALEM		1.27	4.46	0.68	2.39	0.39	1.38	0.00	0.00
82	SAUGUS		0.09	0.34	0.29	1.02	0.24	0.85	0.17	0.59
83	SCITUATE		0.03	0.12	0.17	0.59	0.18	0.64	0.14	0.50
84	SHARON		0.00	0.00	0.34	1.19	0.27	0.95	0.24	0.86
85	SHERBORN		0.00	0.00	0.00	0.00	0.12	0.45	0.09	0.31
86	SOMERVILLE	DI	0.87	3.05	0.19	0.67	0.05	0.19	0.08	0.30
87	SOUTHBOROUGH		0.00	0.00	0.14	0.49	0.17	0.60	0.19	0.66
88	STONEHAM	DI	0.26	0.92	0.19	0.69	0.16	0.56	0.09	0.31

TABLE 5-6
OTHER INDUSTRIAL FLOWS

COMM. NO.	COMMUNITY NAME		OTHER INDUSTRIAL FLOWS (MGD) 1970 AVG.	1970 PEAK	2000 AVG.	2000 PEAK	2020 AVG.	2020 PEAK	2050 AVG.	2050 PEAK
89	STOUGHTON	NI	0.62	2.19	0.73	2.56	0.73	2.57	0.56	1.97
90	STOW		0.00	0.00	0.00	0.00	0.09	0.33	0.07	0.25
91	SUDBURY		0.00	0.00	0.35	1.22	0.35	1.25	0.33	1.16
92	SWAMPSCOTT		0.01	0.06	0.04	0.15	0.04	0.14	0.00	0.02
93	TEWKSBURY		0.00	0.00	0.58	2.05	0.62	2.18	0.37	1.32
94	TOPSFIELD		0.00	0.00	0.06	0.24	0.06	0.23	0.15	0.53
95	WAKEFIELD	DI	0.27	0.96	0.39	1.38	0.38	1.34	0.22	0.77
96	WALPOLE	NI	1.54	5.41	0.61	2.14	0.60	2.13	0.28	1.00
97	WALTHAM	DI	2.84	9.95	1.81	6.36	1.49	5.21	0.59	2.07
98	WATERTOWN	DI	0.75	2.62	0.13	0.46	0.11	0.38	0.13	0.48
99	WAYLAND		0.00	0.00	0.25	0.89	0.26	0.91	0.23	0.82
100	WELLESLEY	NI	0.20	0.70	0.16	0.56	0.16	0.56	0.08	0.28
101	WENHAM		0.00	0.00	0.00	0.00	0.07	0.25	0.11	0.41
102	WESTBOROUGH		0.10	0.37	0.38	1.34	0.44	1.55	0.47	1.67
103	WESTFORD		0.00	0.00	0.34	1.21	0.40	1.41	0.35	1.25
104	WESTON		0.00	0.00	0.10	0.35	0.12	0.42	0.11	0.40
105	WESTWOOD	NI	0.06	0.22	0.12	0.42	0.11	0.41	0.06	0.23
106	WEYMOUTH	NI	0.20	0.71	0.34	1.19	0.29	1.03	0.19	0.67
107	WILMINGTON	DI	0.00	0.00	0.36	1.27	0.36	1.29	0.35	1.25
108	WINCHESTER	DI	0.17	0.60	0.13	0.47	0.10	0.35	0.07	0.26
109	WINTHROP	DI	0.04	0.14	0.01	0.05	0.00	0.00	0.03	0.11
110	WOBURN	DI	1.03	3.61	0.81	2.84	0.54	1.91	0.09	0.34
111	WRENTHAM		0.00	0.00	0.39	1.36	0.44	1.56	0.47	1.66
112	BOSTON PROPER	DI	7.11	24.91	1.92	6.73	1.89	6.62	1.94	6.81
113	BRIGHTON	DI	0.31	1.09	0.10	0.37	0.14	0.49	0.10	0.37
114	CHARLESTOWN	DI	1.40	4.90	0.45	1.57	0.57	2.02	0.57	2.02
115	DORCHESTER	DI	1.47	5.14	1.01	3.54	0.99	3.47	0.63	2.20
116	DORCHESTER	NI	0.00	0.00	0.22	0.78	0.21	0.75	0.08	0.30
117	EAST BOSTON	DI	0.03	0.11	0.14	0.50	0.14	0.50	0.15	0.53
118	FNWY-JMACA	DI	0.51	1.81	0.33	1.17	0.31	1.09	0.29	1.01
119	FNWY-JMACA	NI	0.00	0.00	0.03	0.11	0.02	0.08	0.03	0.11
120	HYDE PARK	NI	0.65	2.28	0.38	1.35	0.35	1.22	0.16	0.57
121	MATTAPAN	NI	0.04	0.14	0.28	1.01	0.28	1.00	0.20	0.72
122	ROSLINDALE	NI	0.20	0.72	0.10	0.36	0.12	0.42	0.09	0.33
123	ROXBURY	DI	1.89	6.64	0.54	1.89	0.51	1.81	0.32	1.15
124	SOUTH BOSTON	DI	2.08	7.28	0.76	2.66	0.75	2.63	0.28	1.00
125	WEST ROXBURY	NI	0.06	0.22	0.04	0.17	0.04	0.15	0.03	0.13

working hours, type of processing (batch or flow through), habits of the operating crews, system capacity, and other similar factors. Generally, industries operate producing peak flows somewhere between 2 and 3.5 times average flows. Generally, 3.5 represents a somewhat constant processing operation over about a seven-hour working day.

In determining whether relief is required for an existing facility, a peak-flow factor of 2.0 was used taking into account the overall dampening of several industries. However, once relief was found to be necessary and where new facilities are required, a factor of 3.5 was used for sizing of such facilities.

The peak flow shown in Table 5-4 represents a peak factor of 3.5.

Process Wastewater Composition

The composition of various pollution components for major industries is shown in Technical Data Vol. 3. For purposes of sizing treatment facilities, for estimating operation costs and as probable parameters for estimating user charges and industrial cost recovery, components selected were BOD and SS.

CHAPTER 6

INFILTRATION/INFLOW

General

In addition to transporting sewage and industrial wastes, extraneous flows enter the sewer system and must be accounted for when determinations are made for facility sizes.

Extraneous flows that must be accounted for in the MDC system include infiltration in the various sewer systems, composed of water entering through defective joints, pipes and manholes; inflow, consisting of water intentionally discharged to the sewer systems through roof leaders, drainage inlets, cross connections, sump pumps and combined sewers; and salt water intrusion, consisting of ocean water entering the sewer systems through faulty tide gates.

Due to the dissimilar characteristics of the various sewer systems, general criteria cannot be used. That is, allowance for extraneous flows from a community with new sewers must be different than for a community where sewers have existed for years.

Similarly, flow records at the Deer and Nut Island treatment plants alone are not sufficient to determine the extent of extraneous flows. For example, during times of rainfall, all flows do not reach the treatment plants. At Deer Island, flows compete for space in the sewer system. When I/I (infiltration/inflow) is low and pipes are not flowing full, ocean water intrudes into the system. (See Appendixes A and B.)

In order that reasonable allowances can be made, records and reports were reviewed on infiltration into EMMA systems. In addition, limited infiltration measurements were made at selected points on the MDC system.

Infiltration allowances adopted represent those judged reasonable on the basis of age and location of a community sewer system and assume that excessive inflow and salinity intrusion would be remedied. This will require review during detailed facilities planning and when I/I studies are conducted.

Analysis of Nut Island Treatment Plant Flows

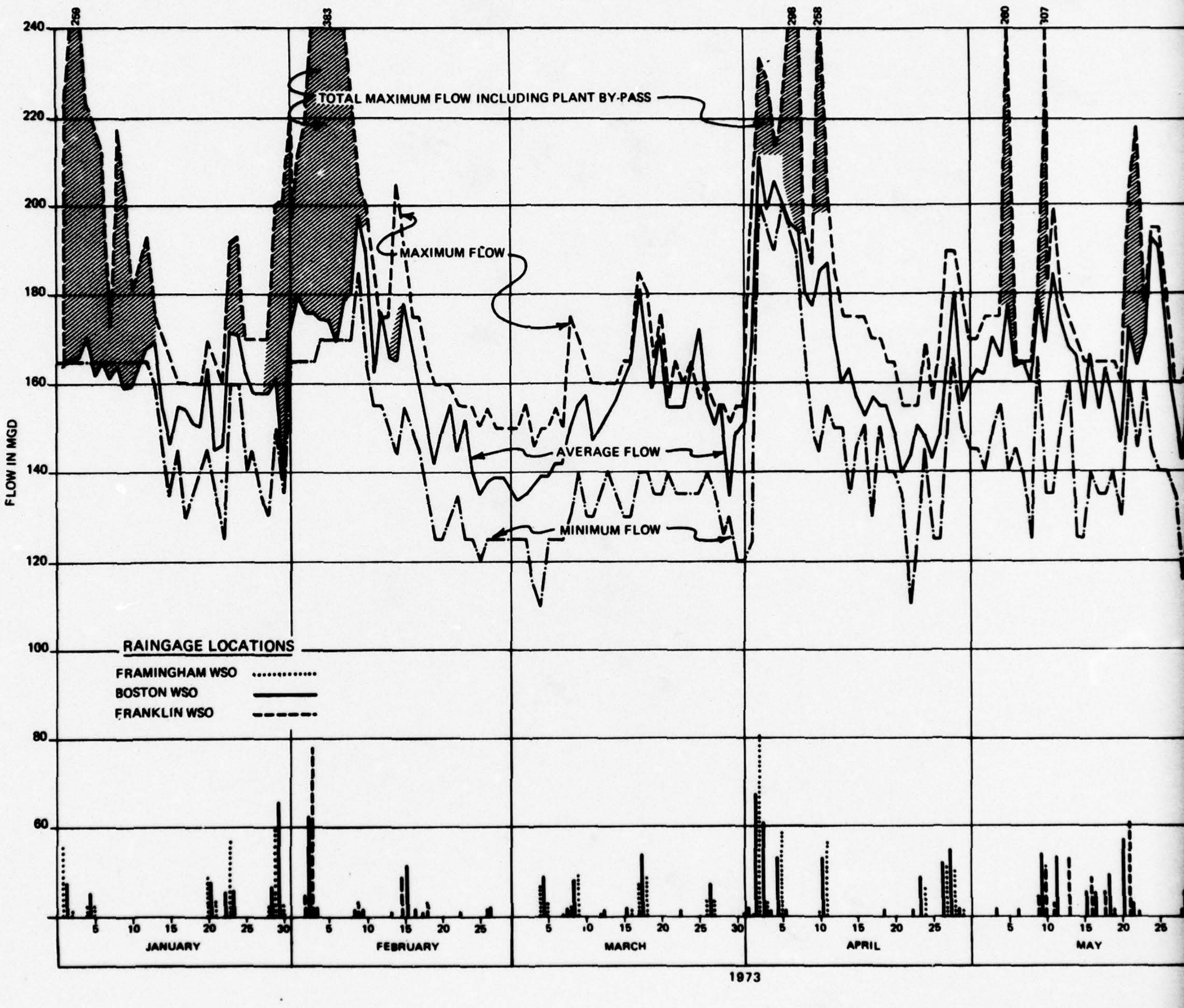
The peak, average and minimum flows at the Nut Island Treatment Plant for each day in 1973 are shown on Figure 6-1. In addition, the flows bypassing the plant by overflowing the weir at the High Level Sewer Terminus are superimposed on the flow data in order to show the total flow reaching the treatment plant.

Also, on Figure 6-1 is shown rainfall data from rain gages in Framingham, Boston and Franklin. The flow increase during the wet season is a measure of wet-weather infiltration and the spontaneous peak flows responding to rainfall conditions is a measure of inflow. As can be seen from Figure 6-1, both infiltration and inflow occur in areas tributary to the Nut Island Treatment Plant. There are no combined sewers tributary to this plant and on the basis of data taken at the plant, salt water intrusion is not a problem. (See Appendix B.)

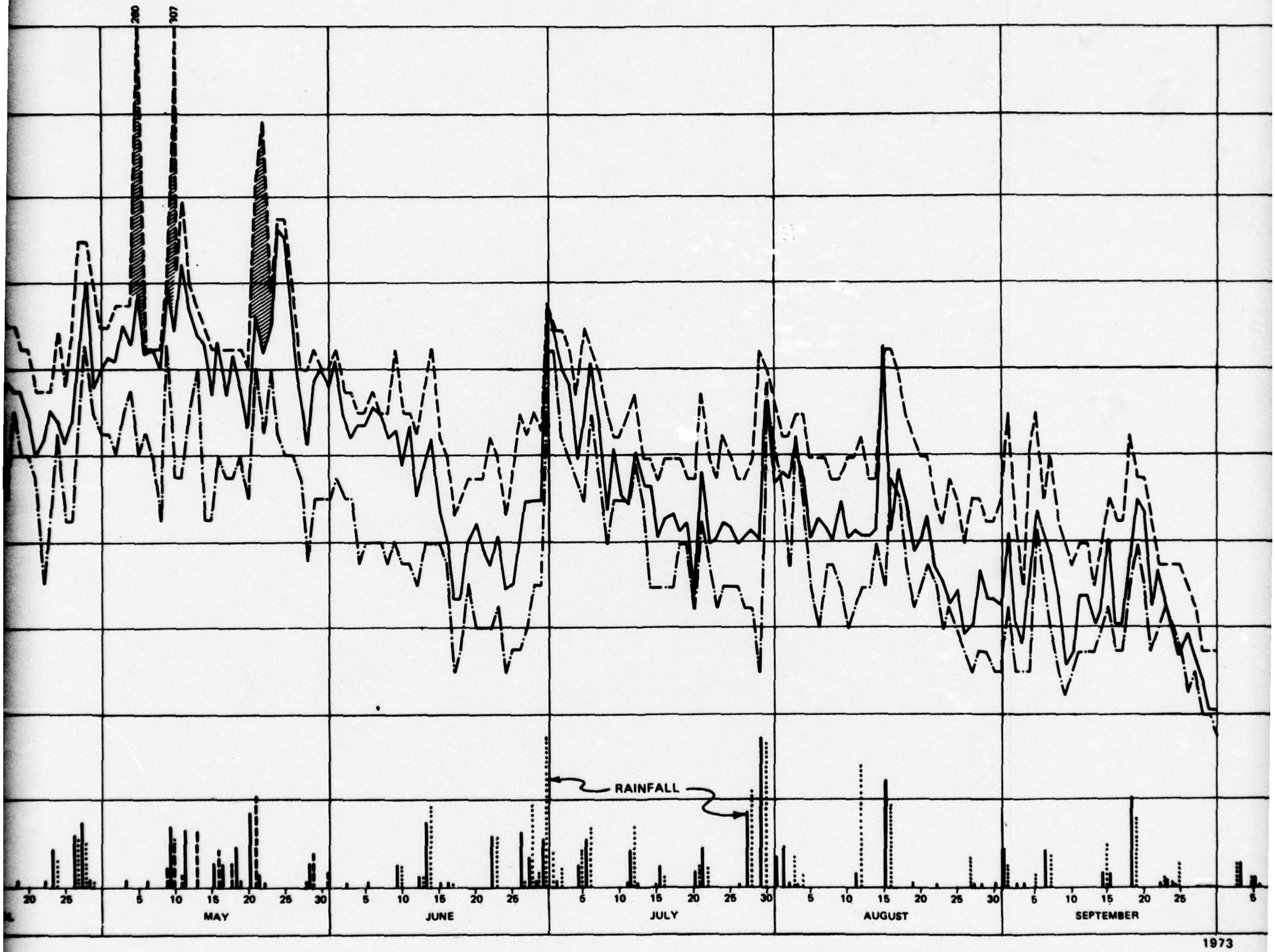
In order to further focus in on I/I at the plant, daily flows for three weeks were plotted, as shown on Figure 6-2. These reflect a fall flow-no rainfall condition to represent minimum flows, a spring flow-no rainfall condition to represent high infiltration, and a spring-wet week condition to represent inflows. Figure 6-2 demonstrates that significant I/I is transmitted to the treatment plant.

As can be seen from Figure 6-1, peak flows for 1973 generally are 200 mgd, except at high rainfall periods, during the spring.

Normally, plant flows can be used to evaluate probable flow categories such as infiltration and industrial flows. For example, a selected percentage of the minimum flow at the plant can be used as a measure of infiltration. Similarly, the difference between weekday and Sunday flows can be used as a measure of industrial and commercial wastes. In the case of the Nut Island Treatment Plant data, however, there are two major factors that prohibit such analysis. First, due to the long travel distance (31 miles maximum) for wastes tributary to the Nut Island Treatment Plant, flows originating at the same time reach the plant at markedly different times. A time difference of between one half to one day occurs for the maximum distances. Second, the large storage capacity in the High Level Sewer (12 million gallons of storage for only



259
383
298
258
280
107
TOTAL MAXIMUM FLOW INCLUDING PLANT BY-PASS
MAXIMUM FLOW
AVERAGE FLOW
MINIMUM FLOW
FLOW IN MGD
240
220
200
180
160
140
120
100
80
60
RAINGAGE LOCATIONS
FRAMINGHAM WSO
BOSTON WSO
FRANKLIN WSO
JANUARY
FEBRUARY
MARCH
APRIL
MAY
1973



280
307
RAINFALL
20 25 5 10 15 20 25 30 5 10 15 20 25 5 10 15 20 25 30 5 10 15 20 25 30 5 10 15 20 25 5
MAY
JUNE
JULY
AUGUST
SEPTEMBER
1973

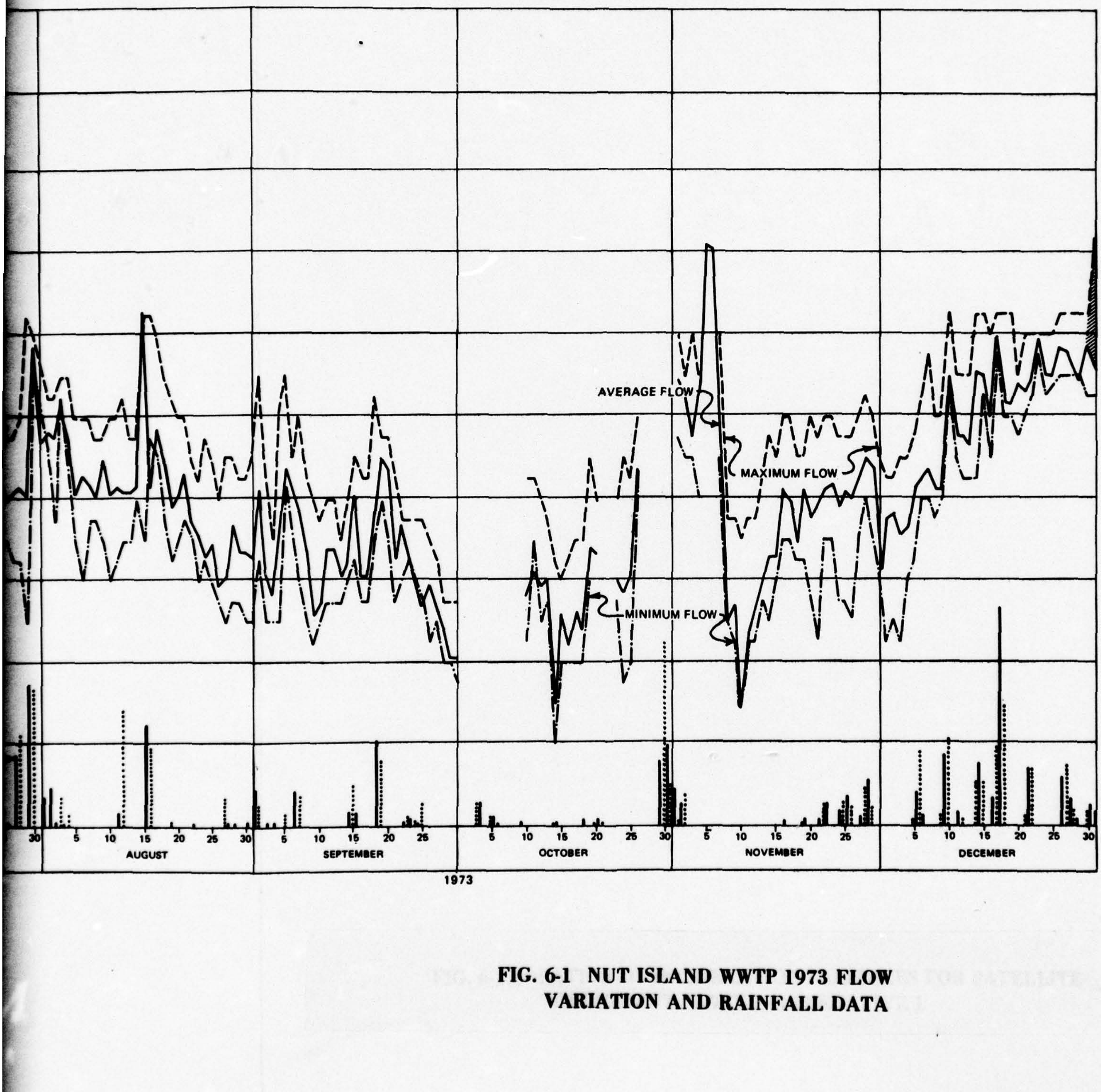


FIG. 6-1 NUT ISLAND WWTP 1973 FLOW VARIATION AND RAINFALL DATA

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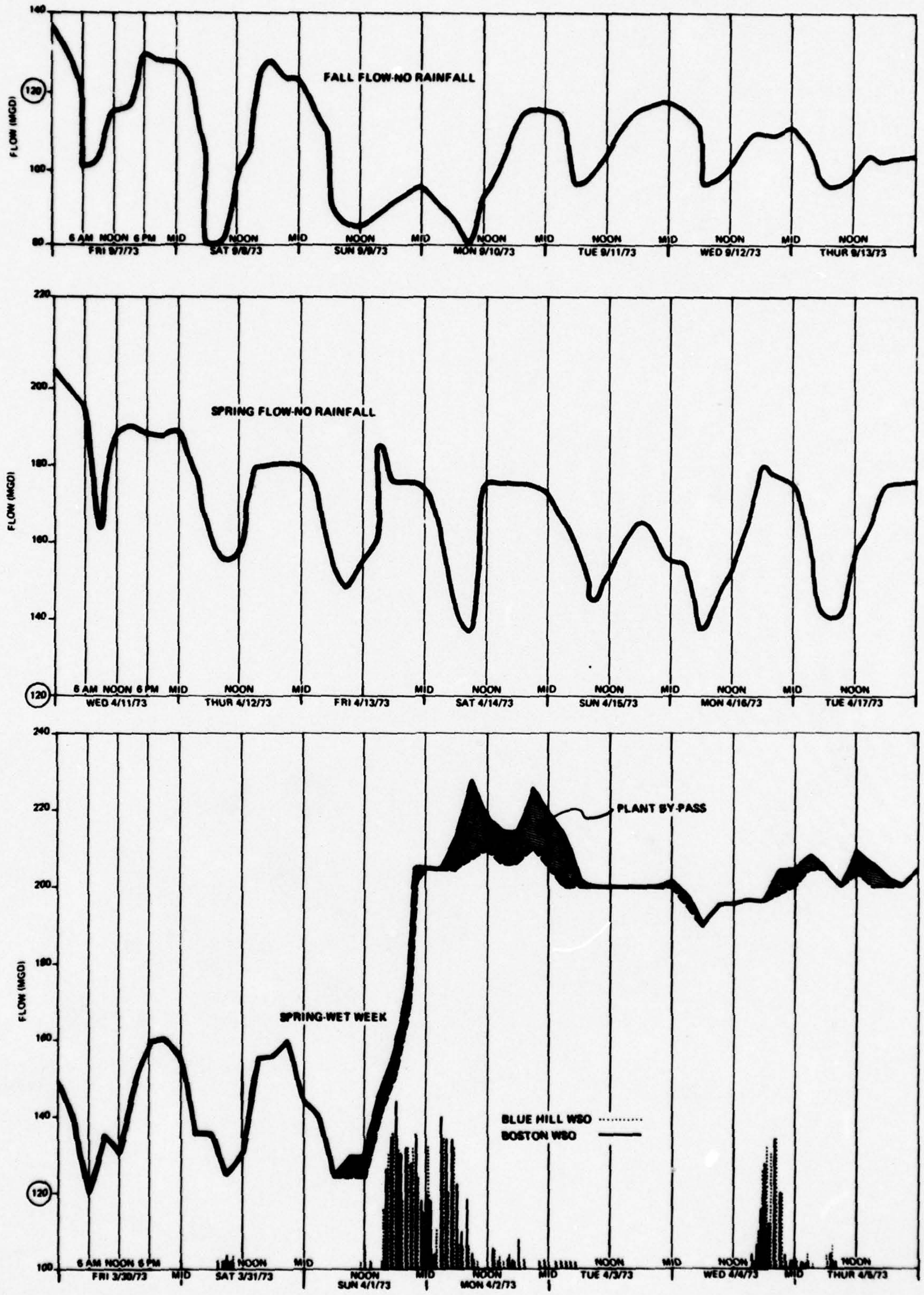


FIG. 6-2 NUT ISLAND WWTP FLOW VARIATION.

the volume below the overflow weir) has an effect on damping flow extremes, the magnitude of which depends upon the operation procedure at the plant.

Analysis of Deer Island Treatment Plant Flows

The peak, average and minimum flows reaching the Deer Island Treatment Plant during 1973 are shown on Figure 6-3. From this, it can be seen that maximum flows generally are under 400 mgd (million gallons per day) except during times of rainfall. The short duration peaks in all cases are in immediate response to rainfall and reflect inflows. This is understandable due to the large proportion (24 percent) of combined sewers.

However, the more critical observation is that flows differ only slightly between dry and wet seasons.

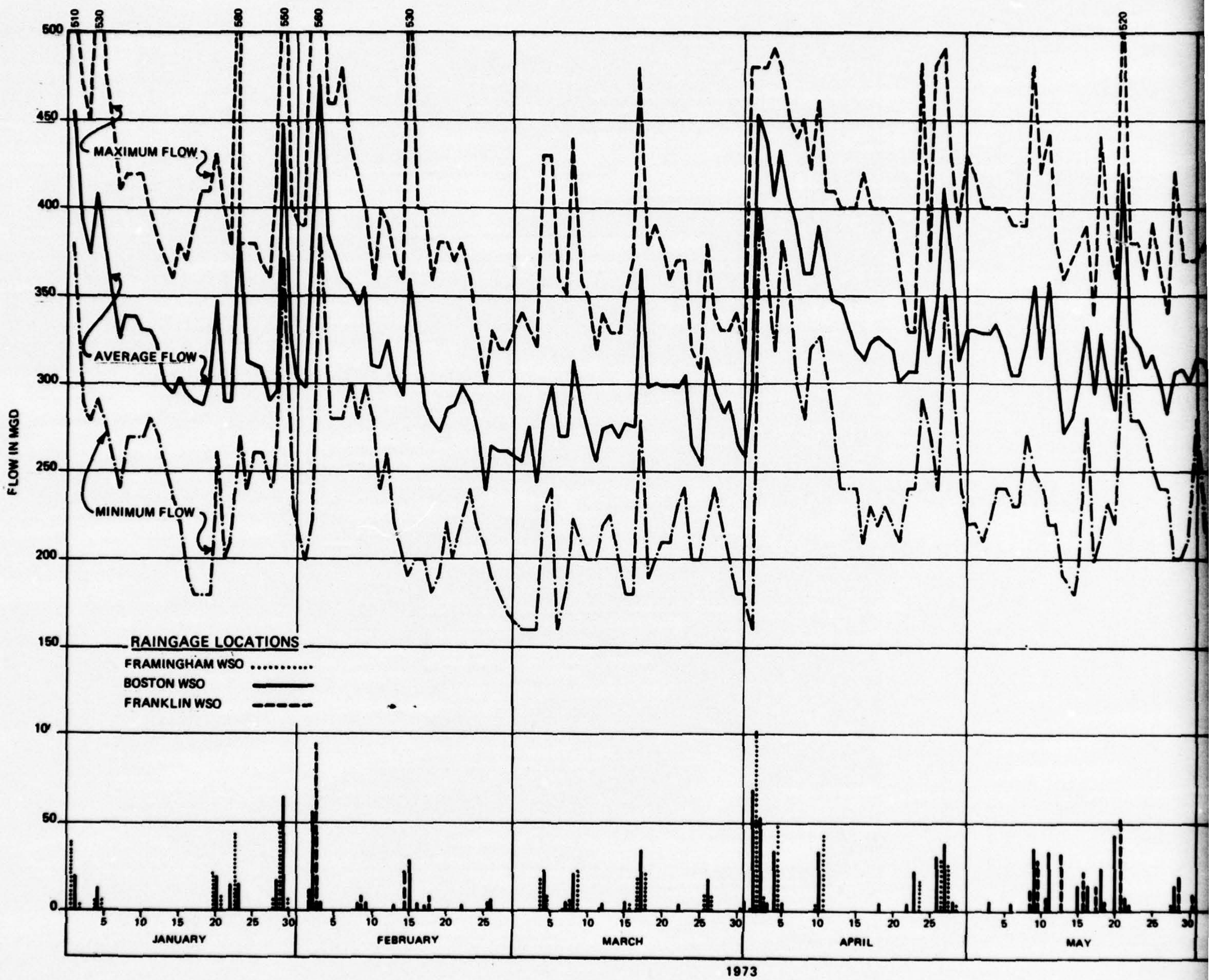
In order to evaluate this further, flows passing through the Chelsea Creek, Columbus Park and Ward Street headworks were plotted as shown respectively on Figures 6-4, 6-5 and 6-6 for three selected weeks. Tidal stages are also shown.

Inspection of Figure 6-5 shows that flows into the Columbus Park Headworks are completely tidally influenced, causing 12-hour oscillations rather than following the normal diurnal pattern. This pattern is only interrupted when rainfall inflow excludes seawater inflow as occurred during the spring wet week. Another factor to note is that low flow conditions remain uniform at 40 mgd during dry and wet seasons.

Conditions at the Chelsea Creek Headworks (Figure 6-4) are also affected by tidal conditions, but to a lesser extent. Also, in this case, there is a rise in low flows from about 80 mgd to about 130 mgd from fall to the spring wet period.

Flows into the Ward Street Headworks as shown on Figure 6-6 also show some tidal influence. As at Columbus Park, low flows do not change over the wet and dry seasons.

From these analyses, it can be seen that flow data at the Deer Island Treatment Plant are severely influenced by inflows and cannot be used as the basis for quantifying the wastewater flows from the various tributary communities.



FLOW IN MGD
500
450
400
350
300
250
200
150
10'
50
0
510
530
580
550
560
530
520
MAXIMUM FLOW
AVERAGE FLOW
MINIMUM FLOW
RAINGAGE LOCATIONS
FRAMINGHAM WSO
BOSTON WSO
FRANKLIN WSO
JANUARY
FEBRUARY
MARCH
APRIL
MAY
1973

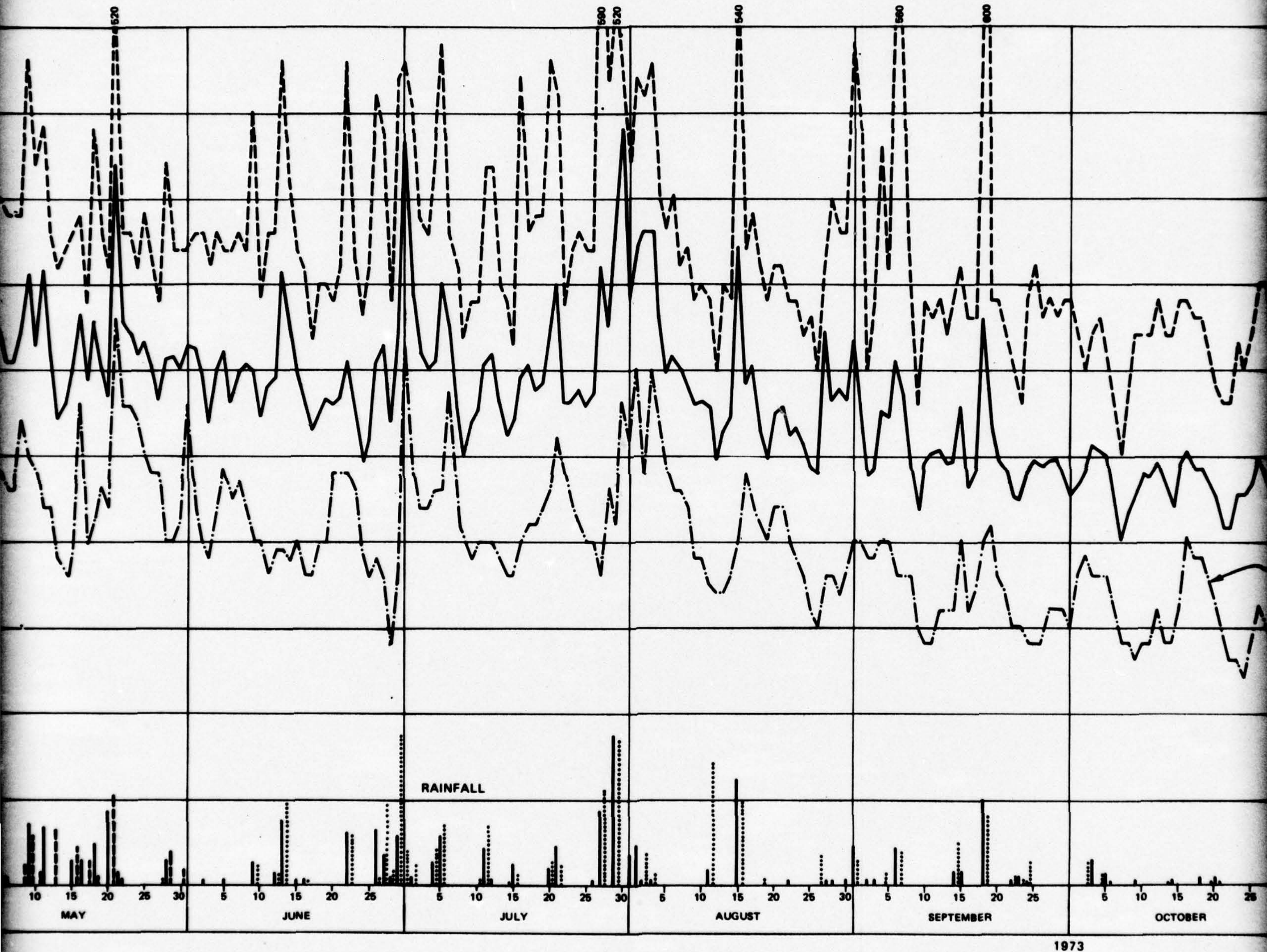


FIG. 6-3 DEER I
VARIATIO

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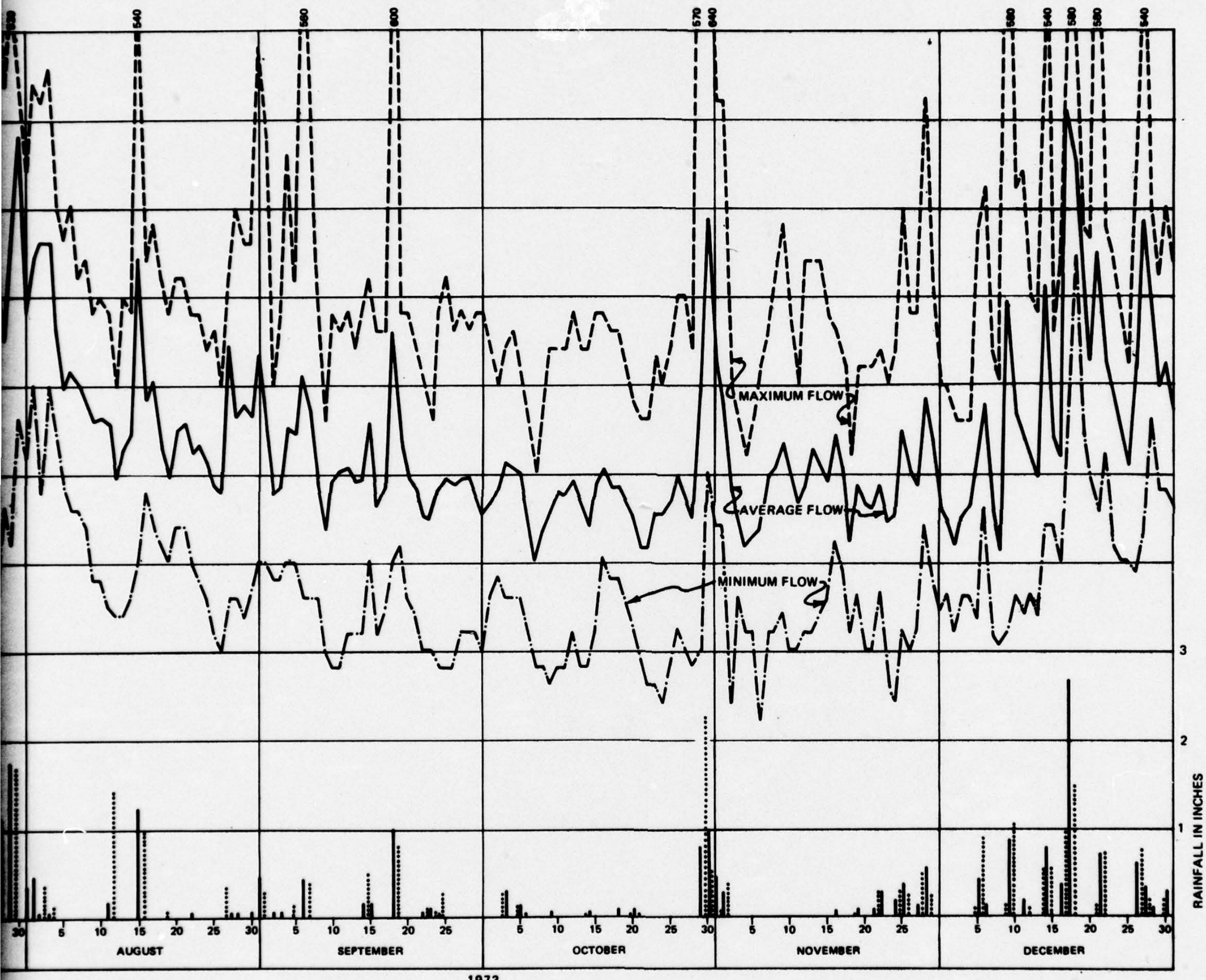

FIG. 6-3 DEER ISLAND WWTP 1973 FLOW VARIATION AND RAINFALL DATA

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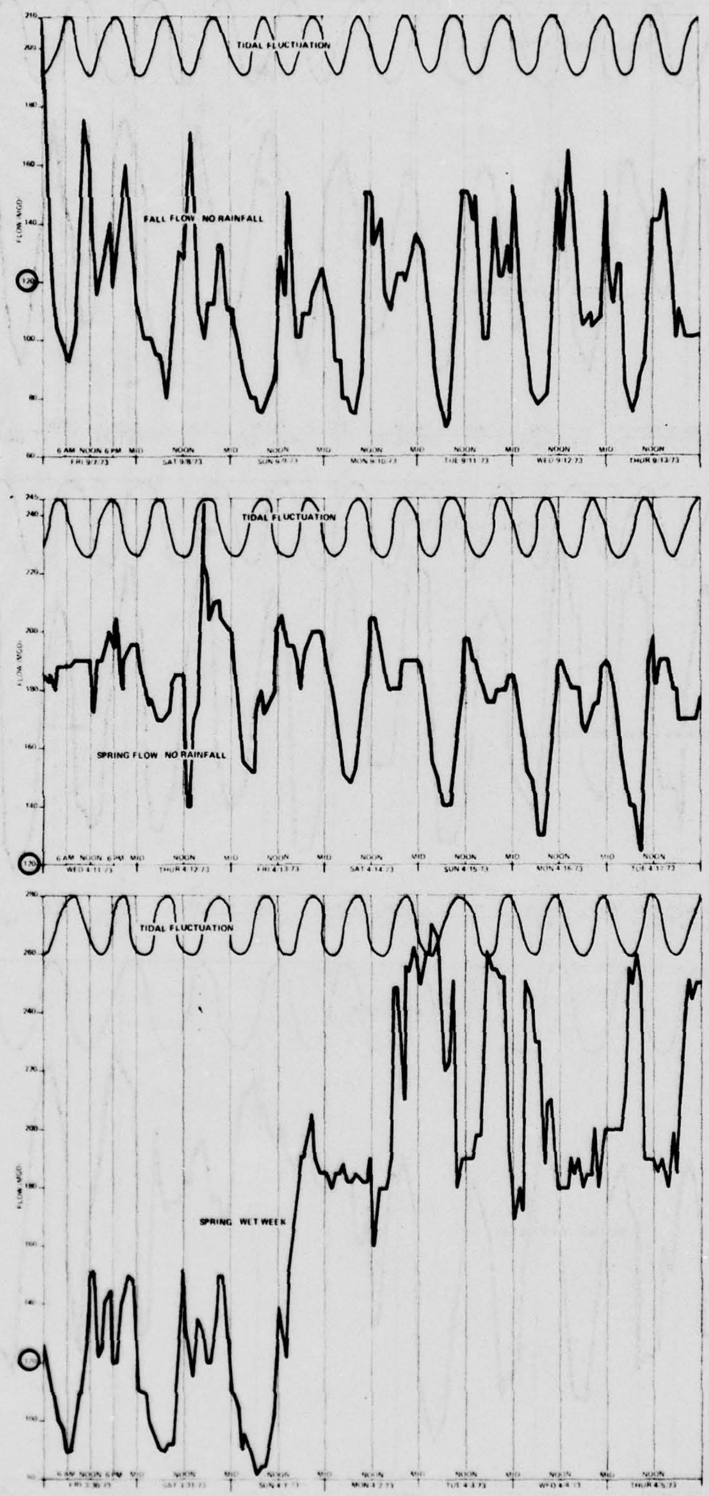


FIG. 6-4 CHELSEA CREEK HEADWORKS FLOW VARIATION

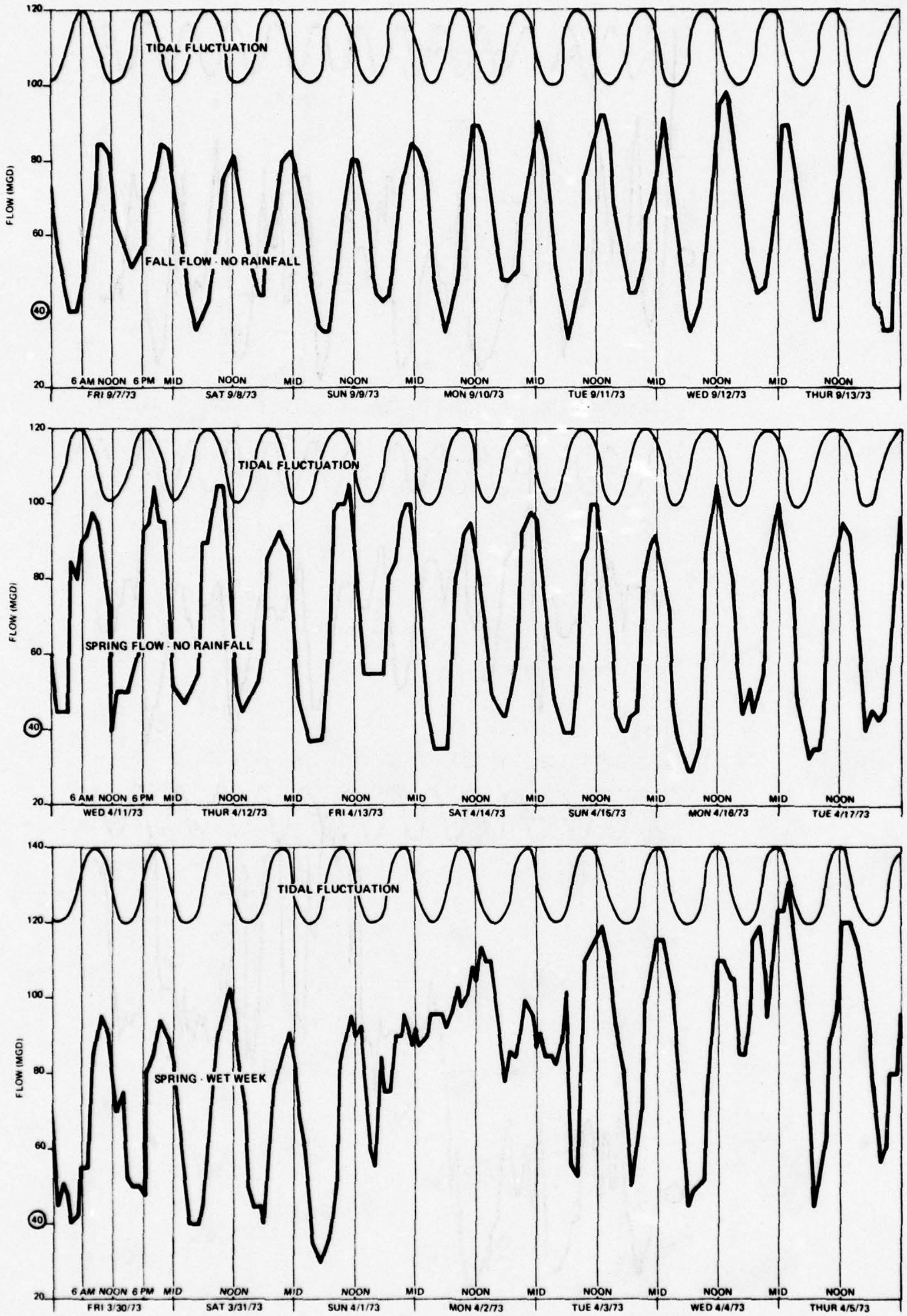


FIG. 6-5 COLUMBUS PARK HEADWORKS FLOW VARIATION

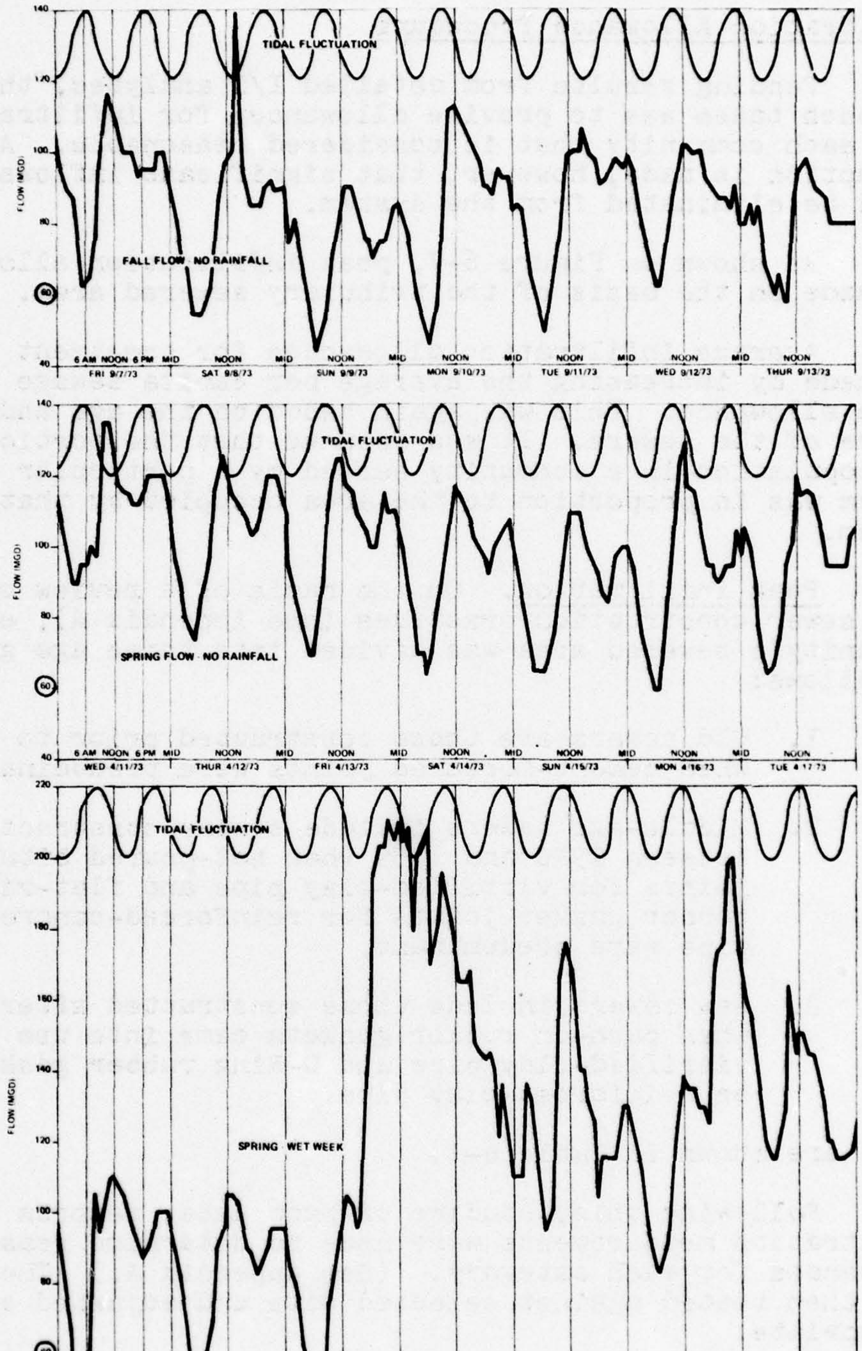


FIG. 6-6 WARD STREET HEADWORKS FLOW VARIATION

Infiltration Allowance Procedure

Pending results from detailed I/I analyses, the approach taken was to provide allowances for infiltration from each community that is considered reasonable. An assumption is made, however, that significant inflows would be eliminated from the system.

As shown on Figure 6-7, peak infiltration allowances are made on the basis of the tributary sewered area.

Average infiltration allowances for treatment plants are made by increasing the average per capita sewage flows by an allowance. This was again based on the age and nature of the sewers. It was assumed that the portion of the population in a community served by a particular age system was in proportion to the area occupied by that system.

Peak Infiltration. On the basis of a review of past sewer construction practices (see Appendix A), each community's sewered area was divided into three age groups as follows:

1. Old sewers are those constructed prior to 1940 when cement-mortared joints were predominant.
2. Middle-age sewers include sewers constructed between 1940 and 1959 when hot-poured bituminous joints for vitrified-clay pipe and flat-ribbed rubber gasket joints for reinforced-concrete pipe were predominant.
3. New sewers include those constructed after 1959 when push-on rubber gaskets came into use on vitrified-clay pipe and O-Ring rubber gaskets on reinforced-clay pipe.

These are shown in Table 6-1.

Following this, studies of past data, reports and infiltration measurements were made to determine reasonable allowances for each category. (See Appendix A.) These were then tested against selected data and adjusted as appropriate.

The adjustment to Figure A-13 consisted of creating an additional category for peak infiltration for very old sewers in the low and combined sewer areas in Boston, Cambridge, Chelsea, Everett, Revere, and Somerville. An

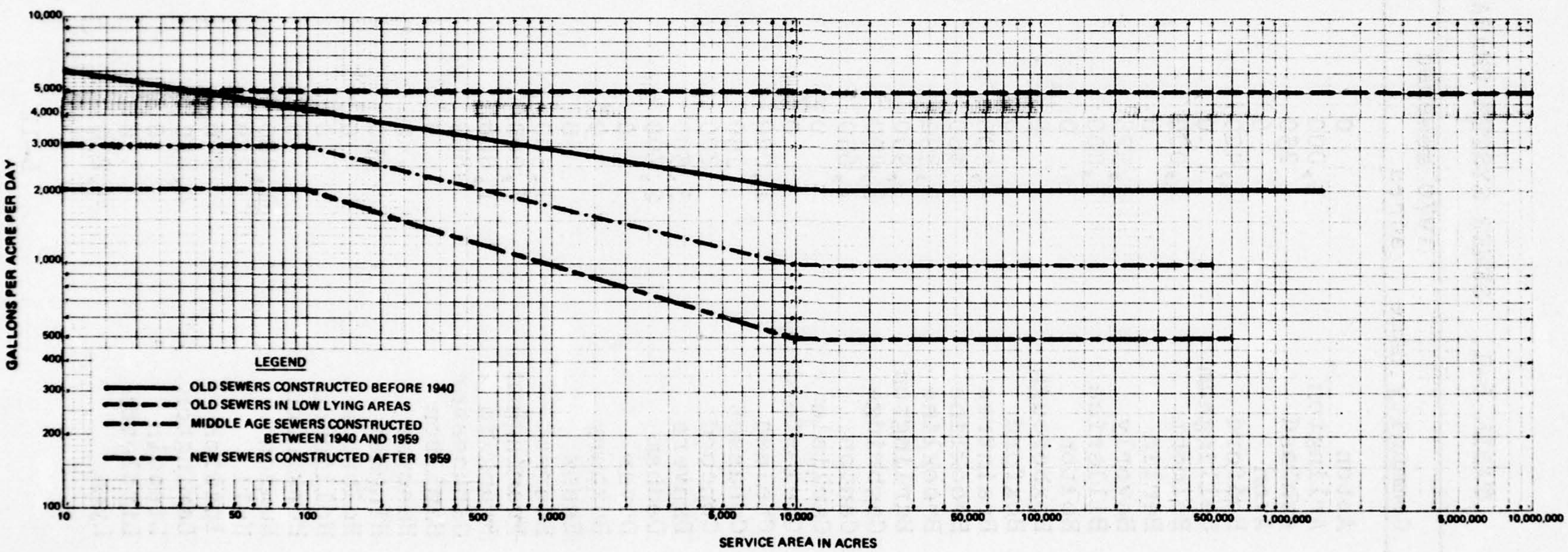


FIG. 6-7 PEAK INFILTRATION RATES

TABLE 6-1. SEWER SYSTEM CHARACTERISTICS

No.	Community name	1970 sewered acres	% of sewered acres New	M.A.	Old
1	Acton	0	100	0	0
2	Arlington	3,000	9	12	79
3	Ashland	250	100	0	0
4	Avon	0	100	0	0
5	Bedford	1,400	89	11	0
6	Bellingham	0	100	0	0
7	Belmont	2,000	13	4	83
8	Berlin	0	100	0	0
9	Beverly	3,525	20	20	60
10	Billerica	1,000	80	20	0
11	Bolton	0	100	0	0
12	Boxborough	0	100	0	0
13	Boxford	0	100	0	0
14	Braintree	4,400	59	15	26
15	Brookline	860	2	2	96
16	Brookline	2,330	2	2	96
17	Burlington	3,900	100	0	0
18	Cambridge	3,400	8	0	92
19	Canton	1,650	82	7	11
20	Carlisle	0	100	0	0
21	Chelmsford	0	100	0	0
22	Chelsea	1,000	0	2	98
23	Cohasset	150	100	0	0
24	Concord	700	5	10	85
25	Danvers	3,500	34	33	33
26	Dedham	2,700	14	28	58
27	Dover	0	100	0	0
28	Duxbury	0	100	0	0
29	Essex	0	100	0	0
30	Everett	1,300	3	1	96
31	Framingham	7,000	43	57	0
32	Franklin	1,000	5	15	80
33	Gloucester	850	10	10	80
34	Hamilton	0	100	0	0
35	Hanover	0	100	0	0
36	Hingham	650	69	31	0
37	Holbrook	0	100	0	0
38	Holliston	0	100	0	0
39	Hopkinton	0	100	0	0
40	Hudson	1,350	20	80	0
41	Hull	350	20	50	30
42	Ipswich	450	100	0	0
43	Lexington	4,400	54	21	25
44	Lincoln	0	100	0	0
45	Littleton	0	100	0	0
46	Lynn	4,250	0	0	100

TABLE 6-1 (Continued). SEWER SYSTEM CHARACTERISTICS

No.	Community name	1970 sewered acres	% of sewered acres New	M.A.	Old
47	Lynnfield	0	100	0	0
48	Malden	2,600	5	3	92
49	Manchester	400	5	5	90
50	Marblehead	2,050	10	10	80
51	Marlborough	3,000	10	10	80
52	Marshfield	25	0	10	90
53	Maynard	850	20	70	10
54	Medfield	100	0	80	20
55	Medford	2,750	2	3	95
56	Medway	16	0	0	100
57	Melrose	2,000	4	8	88
58	Middleton	100	0	100	0
59	Milford	1,500	0	50	50
60	Millis	1,100	0	50	50
61	Milton	230	13	46	41
62	Milton	2,510	13	46	41
63	Nahant	500	0	0	100
64	Natick	3,800	54	46	0
65	Needham	3,600	40	32	28
66	Newton	4,120	5	12	83
67	Newton	6,260	5	12	83
68	Norfolk	0	100	0	0
69	North Reading	0	100	0	0
70	Northborough	0	100	0	0
71	Norwell	0	100	0	0
72	Norwood	3,200	29	22	49
73	Peabody	2,800	0	0	100
74	Pembroke	0	100	0	0
75	Quincy	5,250	5	9	86
76	Randolph	1,800	100	0	0
77	Reading	2,100	61	10	29
78	Revere	1,800	5	17	78
79	Rockland	1,650	100	0	0
80	Rockport	400	10	10	80
81	Salem	2,050	0	0	100
82	Saugus	1,250	34	33	33
83	Scituate	450	80	20	0
84	Sharon	0	100	0	0
85	Sherborn	0	100	0	0
86	Somerville	2,300	0	0	100
87	Southborough	0	100	0	0
88	Stoneham	1,900	36	10	54
89	Stoughton	1,000	35	40	25
90	Stow	0	100	0	0
91	Sudbury	0	100	0	0
92	Swampscott	1,150	10	10	80

TABLE 6-1 (Continued). SEWER SYSTEM CHARACTERISTICS

No.	Community name	1970 sewered acres	% of sewered acres New	M.A.	Old
93	Tewksbury	0	100	0	0
94	Topsfield	0	100	0	0
95	Wakefield	2,250	33	17	50
96	Walpole	1,100	44	4	52
97	Waltham	4,300	25	17	58
98	Watertown	2,100	0	11	89
99	Wayland	0	100	0	0
100	Wellesley	6,200	20	27	53
101	Wenham	0	100	0	0
102	Westborough	1,100	90	10	0
103	Westford	0	100	0	0
104	Weston	0	100	0	0
105	Westwood	600	100	0	0
106	Weymouth	3,050	67	28	5
107	Wilmington	50	100	0	0
108	Winchester	2,550	20	13	67
109	Winthrop	800	0	0	100
110	Woburn	2,100	66	7	27
111	Wrentham	0	100	0	0
112	Boston Proper	1,480	0	0	100
113	Brighton	1,990	0	0	100
114	Charlestown	480	0	0	100
115	Dorchester	2,900	0	0	100
116	Dorchester	410	0	0	100
117	East Boston	1,120	0	0	100
118	Fnwy-Jmaca	1,290	0	0	100
119	Fnwy-Jmaca	490	0	0	100
120	Hyde Park	2,660	0	0	100
121	Mattapan	960	0	0	100
122	Roslindale	1,300	0	0	100
123	Roxbury	2,290	0	0	100
124	South Boston	1,470	0	0	100
125	West Roxbury	1,450	0	0	100

allowance for 5,000 gad (gallons per acre per day) was made for sewers in this area which are tributary to the Deer Island Treatment Plant.

The design parameters for peak infiltration are shown on Figure 6-7.

Average Infiltration. For the three sewer system age groups, average infiltration rates were developed in Appendix A as follows:

Age of system	Per capita allowance in gal.
New	30
Middle age	60
Old	90

However, similar to the peak infiltration allowance procedure, an increased allowance was felt necessary for the very old sewered areas. In this case, Brookline, Quincy, and West Roxbury were added to the previous list. The allowance selected was 120 gcd except in densely populated areas where this exceeded the peak allowance. In those cases, 75 percent of peak was used.

The design allowance for average infiltration are shown in Table 6-2.

TABLE 6-2. AVERAGE INFILTRATION DESIGN ALLOWANCES

Age of system	Average infiltration allowance, gcd
New	30
Middle age	60
Old	90
Very old in low areas	120(1) or 75% of peak(2)

1. Including Cambridge, Chelsea, Everett, Revere, and Somerville.
2. Includes Boston, Brookline and Quincy.

Combined Sewage Flow Considerations

In the sizing of interceptors serving combined sewer areas, past design practice has been to provide for additional capacity to handle a certain amount of stormwater. In the design of the Boston Main Drainage System, an additional allowance was made for inflow of .01 inches per hour (about equal to dry-weather flow). In the early designs of the metropolitan interceptors, an additional allowance for stormwaters of 5 cubic feet (37.4 gallons) per person was made. In the design of the tunnel system, a peak flow of about three times average dry-weather flow

was used in order to allow for combined sewage. The overall concept was that flows in excess of this would have sufficient dilution so as not to cause pollution problems. More recent approaches to management of combined sewer overflows indicate that little benefit is gained by intercepting portions of overflows unless such interception is significant. As presented in Technical Data Vol. 7, Combined Sewer Overflow Regulation, specific facilities are proposed to abate pollution from combined sewer overflows. It is, therefore, not considered practical to maintain a set interception ratio of three times dry-weather flow when the overflowing combined sewage has to be managed for pollution abatement in any event. On this basis, testing for adequacy of interceptors serving areas including combined sewers is on the basis of peak dry-weather flow. Where such flow increases with time, the present interception ratio is reduced to less than three.

Infiltration Allowances Selected

The infiltration allowances selected are shown in Table 6-3.

TABLE 6-3
INFILTRATION FLOWS

COMM. NO.	COMMUNITY NAME		1970 AVG.	1970 PEAK	2000 AVG.	2000 PEAK	2020 AVG.	2020 PEAK	2050 AVG.	2050 PEAK
1	ACTON		0.00	0.00	0.59	1.78	1.22	2.68	1.70	2.86
2	ARLINGTON	DI	4.32	6.38	4.36	6.38	4.28	6.38	3.64	6.38
3	ASHLAND	NI	0.03	0.37	0.47	1.84	0.66	2.20	0.79	2.46
4	AVON		0.00	0.00	0.20	0.82	0.29	1.00	0.34	1.03
5	BEDFORD	DI	0.20	1.37	0.52	2.67	0.55	2.77	0.44	2.77
6	BELLINGHAM		0.00	0.00	0.41	1.32	0.53	1.64	0.79	1.93
7	BELMONT	DI	1.97	4.61	2.26	4.61	2.20	4.61	2.20	4.61
8	BERLIN		0.00	0.00	0.00	0.00	0.28	1.22	0.68	2.28
9	BEVERLY		2.43	6.37	3.25	7.10	3.57	7.29	3.77	7.29
10	BILLERICA		0.11	1.14	1.07	2.87	1.50	3.54	1.46	3.54
11	BOLTON		0.00	0.00	0.00	0.00	0.18	0.90	0.88	2.22
12	BOXBOROUGH		0.00	0.00	0.00	0.00	0.27	1.17	0.68	1.84
13	BOXFORD		0.00	0.00	0.00	0.00	0.34	1.42	0.88	2.73
14	BRAINTREE	NI	1.72	5.08	2.30	5.25	2.47	5.37	2.57	5.40
15	BROOKLINE	DI	1.87	2.49	1.87	2.49	1.87	2.49	1.87	2.49
16	BROOKLINE	NI	4.32	5.76	4.36	5.81	4.36	5.81	4.36	5.81
17	BURLINGTON	DI	0.32	2.58	0.99	3.24	0.97	3.24	0.73	3.24
18	CAMBRIDGE	DI	11.24	15.69	11.97	15.69	11.62	15.69	10.22	15.69
19	CANTON	NI	0.34	1.82	1.08	3.41	1.39	3.80	1.66	3.94
20	CARLISLE		0.00	0.00	0.00	0.00	0.27	1.20	0.73	2.40
21	CHELMSFORD		0.00	0.00	0.86	2.69	1.54	3.92	1.61	3.92
22	CHELSEA	DI	3.61	4.89	2.42	4.89	2.21	4.89	2.33	4.89
23	COHASSET		0.01	0.26	0.25	1.13	0.45	1.71	0.50	1.94
24	CONCORD		0.54	1.98	1.01	2.91	1.53	3.77	2.04	4.53
25	DANVERS		1.21	5.05	1.75	5.53	1.97	5.68	1.75	5.68
26	DEDHAM	NI	1.73	5.13	1.89	5.36	1.90	5.40	1.54	5.40
27	DOVER		0.00	0.00	0.00	0.00	0.13	0.73	0.37	1.50
28	DUXBURY		0.00	0.00	0.00	0.00	0.13	0.74	0.40	1.57
29	ESSEX		0.00	0.00	0.09	0.55	0.27	1.21	0.48	1.79
30	EVERETT	DI	4.93	6.26	4.13	6.26	3.68	6.26	3.11	6.26
31	FRAMINGHAM	NI	2.36	5.97	3.62	6.68	3.89	6.80	3.82	6.80
32	FRANKLIN		0.68	2.61	1.12	3.49	1.55	4.24	1.99	4.94
33	GLOUCESTER		1.33	2.25	1.75	2.66	2.00	2.88	2.12	2.98
34	HAMILTON		0.00	0.00	0.20	0.98	0.51	1.86	0.80	2.55
35	HANOVER		0.00	0.00	0.50	1.83	0.70	2.31	0.90	2.57
36	HINGHAM	NI	0.14	0.90	0.61	2.44	0.97	3.35	1.00	3.43
37	HOLBROOK	NI	0.00	0.00	0.39	1.16	0.46	1.30	0.76	1.73
38	HOLLISTON		0.00	0.00	0.30	1.29	0.69	2.30	0.99	2.79
39	HOPKINTON		0.00	0.00	0.27	1.19	0.69	2.26	1.21	2.78
40	HUDSON		0.66	1.98	1.05	2.69	1.20	2.95	1.23	3.00
41	HULL		0.20	0.84	0.33	1.19	0.32	1.19	0.35	1.23
42	IPSWICH		0.12	0.57	0.48	1.47	0.67	1.85	0.89	2.24
43	LEXINGTON	DI	1.26	5.14	1.70	6.06	2.19	6.28	2.35	6.30
44	LINCOLN		0.00	0.00	0.16	0.85	0.33	1.38	0.82	2.59

TABLE 6-3
INFILTRATION FLOWS

COMM. NO.	COMMUNITY NAME		INFILTRATION FLOW (MGD) 1970 AVG.	1970 PEAK	2000 AVG.	2000 PEAK	2020 AVG.	2020 PEAK	2050 AVG.	2050 PEAK
45	LITTLETON		0.00	0.00	0.16	0.85	0.54	1.95	0.96	2.47
46	LYNN		8.04	9.73	7.53	9.73	7.25	9.73	6.65	9.73
47	LYNNFIELD		0.00	0.00	0.37	1.49	0.54	1.88	0.69	2.02
48	MALDEN	DI	4.80	6.08	4.36	6.08	4.11	6.08	3.36	6.08
49	MANCHESTER		0.28	1.26	0.50	1.87	0.66	2.23	0.69	2.35
50	MARBLEHEAD		1.63	4.68	1.68	4.68	1.61	4.68	1.53	4.68
51	MARLBOROUGH		1.35	6.42	2.07	6.82	2.67	7.08	2.78	7.21
52	MARSHFIELD		0.02	0.12	0.74	2.43	1.11	3.23	1.37	3.66
53	MAYNARD		0.49	1.50	0.57	1.66	0.62	1.74	0.56	1.74
54	MEDFIELD		0.09	0.32	0.52	1.13	0.76	1.48	1.01	1.80
55	MEDFORD	DI	5.57	6.52	5.88	6.52	5.70	6.52	5.21	6.52
56	MEDWAY		0.02	0.08	0.23	1.05	0.47	1.71	0.67	1.92
57	MELROSE	DI	2.81	4.82	3.23	4.82	3.31	4.82	3.18	4.82
58	MIDDLETON		0.00	0.00	0.09	0.55	0.24	1.10	0.45	1.71
59	MILFORD		1.32	3.20	1.45	3.38	1.57	3.54	1.65	3.64
60	MILLIS		0.10	2.49	0.59	3.00	0.90	3.41	1.19	3.67
61	MILTON	DI	0.33	0.64	0.33	0.66	0.33	0.66	0.35	0.67
62	MILTON	NI	1.41	4.40	1.72	4.91	1.98	5.09	2.04	5.09
63	NAHANT		0.34	1.60	0.34	1.60	0.33	1.60	0.42	1.60
64	NATICK	NI	0.93	3.57	1.48	4.22	1.81	4.35	1.73	4.35
65	NEEDHAM	NI	1.44	4.82	2.22	5.24	2.57	5.43	2.89	5.43
66	NEWTON	DI	3.40	8.56	4.05	8.56	4.16	8.56	4.12	8.56
67	NEWTON	NI	4.14	12.14	4.72	12.14	5.05	12.14	5.17	12.14
68	NORFOLK		0.00	0.00	0.00	0.00	0.18	0.90	0.50	1.83
69	NORTH READING		0.00	0.00	0.39	1.38	0.59	1.84	0.78	1.97
70	NORTHBOROUGH		0.00	0.00	0.44	1.33	0.75	1.84	1.16	2.13
71	NORWELL		0.00	0.00	0.20	0.96	0.31	1.34	0.84	2.24
72	NORWOOD	NI	2.01	5.33	2.45	5.38	2.49	5.41	2.21	5.41
73	PEABODY		2.68	6.85	3.50	7.63	3.53	7.63	3.19	7.63
74	PEMBROKE		0.00	0.00	0.22	1.04	0.31	1.32	0.70	2.32
75	QUINCY	NI	7.99	10.65	7.99	10.65	7.99	10.65	7.99	10.65
76	RANDOLPH	NI	0.40	1.50	0.92	2.45	0.93	2.45	0.86	2.45
77	READING	DI	0.68	2.88	1.20	3.61	1.42	3.62	1.70	3.62
78	REVERE	DI	4.25	7.52	4.77	7.55	4.58	7.55	4.28	7.55
79	ROCKLAND		0.09	1.41	0.29	1.90	0.54	1.94	0.49	1.94
80	ROCKPORT		0.27	1.20	0.45	1.71	0.57	1.98	0.69	2.24
81	SALEM		3.50	5.27	3.38	5.27	3.18	5.27	2.57	5.27
82	SAUGUS		0.84	2.23	1.15	2.72	1.23	2.83	1.16	2.83
83	SCITUATE		0.06	0.64	0.47	1.77	0.76	2.46	0.93	2.84
84	SHARON		0.00	0.00	0.32	1.34	0.73	2.36	1.17	2.73
85	SHERBORN		0.00	0.00	0.00	0.00	0.16	0.85	0.41	1.61
86	SOMERVILLE	DI	10.64	11.50	8.28	11.50	8.23	11.50	8.16	11.50
87	SOUTHBOROUGH		0.00	0.00	0.21	0.90	0.46	1.40	0.86	1.65
88	STONEHAM	DI	1.28	3.50	1.36	3.54	1.27	3.54	1.35	3.54

TABLE 6-3
INFILTRATION FLOWS

COMM. NO.	COMMUNITY NAME		INFILTRATION FLOW (MGD) 1970 AVG.	1970 PEAK	2000 AVG.	2000 PEAK	2020 AVG.	2020 PEAK	2050 AVG.	2050 PEAK
89	STOUGHTON	NI	0.32	1.77	1.21	3.20	1.52	3.42	1.61	3.53
90	STOW		0.00	0.00	0.00	0.00	0.14	0.76	0.42	1.63
91	SUDBURY		0.00	0.00	0.62	2.14	1.36	3.69	1.86	4.29
92	SWAMPSCOTT		1.03	2.89	1.39	2.89	1.45	2.90	1.57	2.92
93	TEWKSBURY		0.00	0.00	0.77	2.07	1.02	2.53	1.17	2.64
94	TOPSFIELD		0.00	0.00	0.14	0.75	0.43	1.65	0.67	2.27
95	WAKEFIELD	DI	1.45	3.96	2.10	4.17	2.28	4.23	2.54	4.26
96	WALPOLE	NI	0.36	2.15	1.09	4.18	1.57	4.66	1.89	4.88
97	WALTHAM	DI	3.22	7.27	5.27	7.62	5.26	7.62	4.93	7.62
98	WATERTOWN	DI	3.40	5.12	2.74	5.12	2.65	5.12	2.58	5.12
99	WAYLAND		0.00	0.00	0.50	1.85	1.09	3.17	1.37	3.49
100	WELLESLEY	NI	1.58	9.62	2.20	9.62	2.27	9.62	2.01	9.62
101	WENHAM		0.00	0.00	0.00	0.00	0.14	0.78	0.37	1.47
102	WESTBOROUGH		0.12	1.14	0.47	2.80	0.80	3.10	1.06	3.34
103	WESTFORD		0.00	0.00	0.19	0.96	0.53	1.93	1.34	3.13
104	WESTON		0.00	0.00	0.51	1.87	0.78	2.50	0.73	2.50
105	WESTWOOD	NI	0.13	0.69	0.68	2.24	0.82	2.55	0.89	2.68
106	WEYMOUTH	NI	1.16	2.99	2.08	4.13	2.20	4.17	2.19	4.17
107	WILMINGTON	DI	0.00	0.00	0.81	2.09	1.10	2.44	1.15	2.44
108	WINCHESTER	DI	1.63	5.05	1.85	5.05	1.74	5.05	1.61	5.05
109	WINTHROP	DI	1.83	2.38	1.31	2.38	1.09	2.38	1.23	2.38
110	WOBURN	DI	1.33	2.76	2.01	3.57	2.05	3.61	1.80	3.61
111	WRENTHAM		0.00	0.00	0.21	1.00	0.59	1.91	1.13	2.39
112	BOSTON PROPER	DI	5.54	7.39	5.54	7.39	5.54	7.39	5.54	7.39
113	BRIGHTON	DI	7.46	9.94	7.46	9.94	7.46	9.94	7.46	9.94
114	CHARLESTOWN	DI	1.79	2.40	1.79	2.40	1.79	2.40	1.79	2.40
115	DORCHESTER	DI	10.87	14.50	10.87	14.50	10.87	14.50	10.87	14.50
116	DORCHESTER	NI	1.02	1.36	1.02	1.36	1.02	1.36	1.02	1.36
117	EAST BOSTON	DI	4.19	5.59	4.19	5.59	4.19	5.59	4.19	5.59
118	FNWY-JMACA	DI	4.83	6.44	4.83	6.44	4.83	6.44	4.83	6.44
119	FNWY-JMACA	NI	1.18	1.58	1.18	1.58	1.18	1.58	1.18	1.58
120	HYDE PARK	NI	4.92	6.56	4.92	6.56	4.92	6.56	4.92	6.56
121	MATTAPAN	NI	2.08	2.78	2.08	2.78	2.08	2.78	2.08	2.78
122	ROSLINDALE	NI	2.69	3.59	2.69	3.59	2.69	3.59	2.69	3.59
123	ROXBURY	DI	8.58	11.44	8.58	11.44	8.58	11.44	8.58	11.44
124	SOUTH BOSTON	DI	5.51	7.34	5.51	7.34	5.51	7.34	5.51	7.34
125	WEST ROXBURY	NI	2.95	3.93	2.95	3.93	2.95	3.93	2.95	3.93

CHAPTER 7

TREATMENT CRITERIA

General

Wastewater treatment systems are composed of unit operations in which the application of physical forces predominate and unit processes in which removal of pollutants is accomplished primarily by biological or chemical phenomena. Combinations of unit operations and processes have historically provided an extent of treatment known as primary or secondary. Treatment requirements beyond that provided by secondary unit operations have conventionally been termed as "tertiary treatment" or "advanced wastewater treatment." Since the extent of treatment inferred by these terms is arbitrary, that treatment required beyond EPA-defined secondary may be determined by establishing the contaminant removals required prior to discharge or land application. The available unit operations and unit processes may then be grouped together on the basis of compatibility and performance criteria to obtain technologically feasible categories of effluent quality.

The conventional objectives of wastewater treatment are removal of (1) biodegradable organics, (2) suspended solids, (3) nutrients (nitrogen and phosphorus), and (4) destruction of pathogenic organisms by disinfection.

The objectives of secondary treatment have been the removal of biodegradable organics and suspended solids and disinfection. More stringent standards have recently focused on nutrient removal for control of eutrophication and ultimate oxygen demand.

Treatment Processes

Various technologies are available and are becoming available for wastewater treatment. The five major wastewater treatment systems usually considered are activated sludge, fixed film, lagoons and ponds, land application, and physical-chemical. The process selected for determining costs, area requirements and developing general layouts is the activated-sludge process.

Preliminary Treatment. The main objective of preliminary treatment is the removal of coarse solids. This is usually accomplished with bar racks or screens.

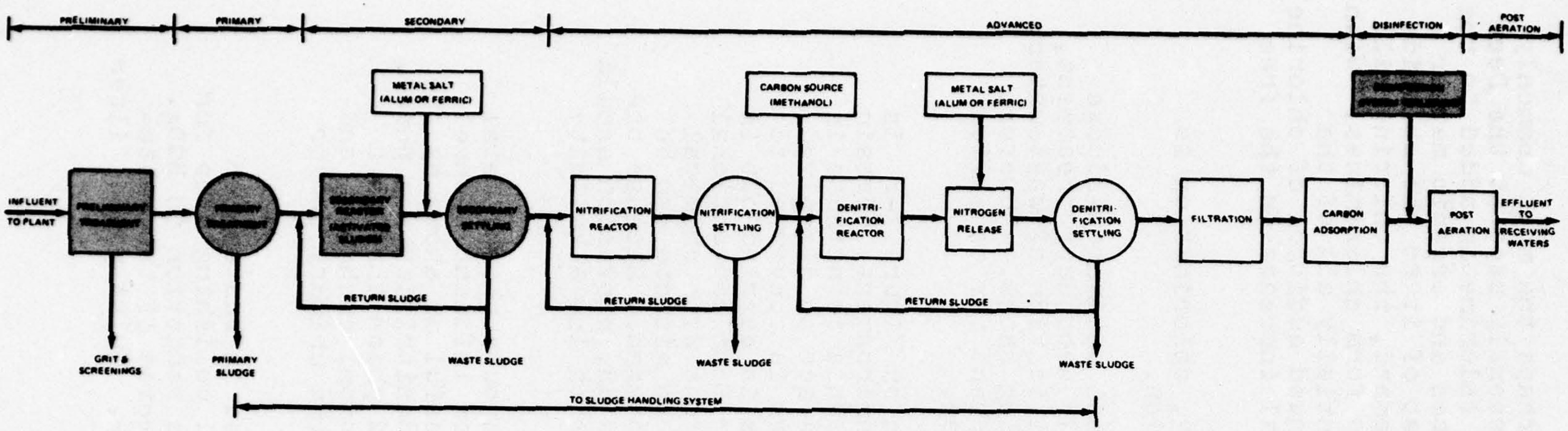
Comminutors are sometimes used in place of racks or screens to grind up the solids without removing them from the wastewater. Grit chambers are designed to remove grit, consisting of sand, gravel, cinders, or other heavy solid materials that have settling velocities or specific gravities substantially greater than those of the organic putrescible solids in wastewater. Skimming tanks, grease traps, preaeration, and flocculation are additional processes that may be used to make primary treatment more effective.

Primary Treatment. Primary sedimentation is used to remove settleable and floating material from wastewater under quiescent conditions. Sludge is collected in a hopper at the bottom of the tank and scum is skimmed from the surface. Chemicals may be added to promote the precipitation of phosphorus compounds, BOD_5 (5-day biochemical oxygen demand) and SS.

Secondary Treatment. The activated-sludge process uses suspended microorganisms to oxidize soluble and colloidal organics contained in domestic wastewaters. During the oxidation process, new cells are synthesized. Some of the synthesized cells undergo auto-oxidation in the aeration tank, the remainder forming excess sludge. Oxygen is required in the process to support the oxidation and synthesis reactions. The solids generated must be separated in a settling tank, with the largest portion returned to the aeration tank, and the excess sludge withdrawn from the system for further handling and disposal. Due to the flexibility of the process, an activated-sludge plant may have various modifications.

The step aeration process was selected in the preliminary plant layouts made. In this process, the influent wastewater is introduced at several points along the aeration tank. The return sludge is introduced at the head end of the tank as in the conventional process. The process can accept higher volumetric loadings than the conventional process without any reduction in treatment efficiency. Since the incoming flow is distributed along the length of the aeration tank, the initial oxygen demand is reduced below that experienced in the conventional process. Volumetric loading is 40-60 pounds BOD_5 per day per 1,000 cubic feet. The organic loading in F/M (food-to-microorganisms) ratio is 0.2-0.4 pounds BOD_5 per pound per MLSS (mixed-liquor suspended solids) per day.

Figure 7-1 shows the treatment train and effluent criteria for this.



EFFLUENT PARAMETER	MONTHLY AVERAGE LIMIT NO FILTRATION
BOD_5	30 mg/L
SS	30 mg/L
FECAL COLIFORM BACTERIA	200/100 ml
pH	6.0-9.0

FIG. 7-1 TREATMENT TRAIN AND EFFLUENT CRITERIA FOR SECONDARY TREATMENT

Disinfection. Chlorine is perhaps the most commonly used chemical disinfectant and is presently used at the Deer and Nut Island treatment plants. As chlorine is added to the effluent, readily oxidizable substances and organic matter react with the chlorine, reducing most of it to the chloride ion. After meeting this immediate demand, the chlorine will continue to react with the ammonia to form chloramines. With continued addition of chlorine, essentially all of the chloramines will be oxidized. Continued addition of chlorine will result in a directly proportional increase in the free available chlorine.

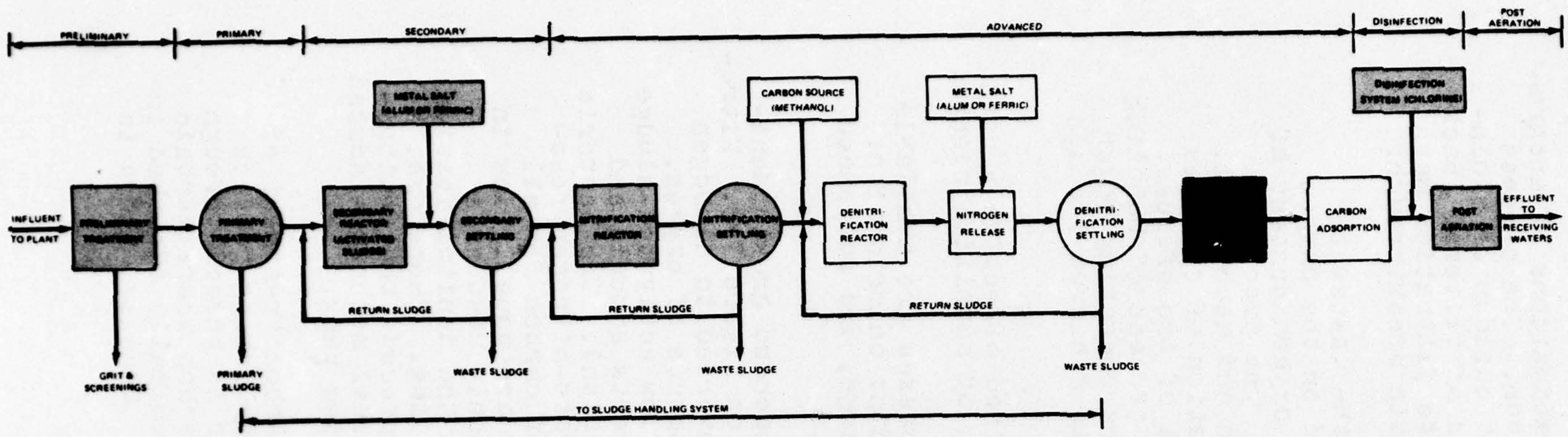
For the purposes of this study, chlorination is continued as the method of disinfection.

Nitrification. The conventional activated-sludge process, as previously described under secondary treatment, can be used to provide seasonal nitrification of wastewater effluent at conservative design loading rates. However, as presently established, the requirement for satellite plants is for continuous nitrification.

The process selected, as shown on Figure 7-2, is suspended growth. In a controlled environment, certain microbial population will convert ammonia to nitrate in the presence of oxygen. Nitrosomonas act on dissolved ammonia to form nitrite, which in turn is converted to nitrate by Nitrobacter. This process is carried out in an activated-sludge system downstream from conventional secondary treatment or primary treatment with chemical additions. The oxidation of ammonia to nitrate can be carried out with either air or pure oxygen. Because the microbial conversion causes a drop in pH, provision should be made for lime or caustic additon with low alkalinity wastewaters.

Phosphorus Removal. In the layouts shown, metal salts are added to the final clarifier influent channel. Multipoint additions have been successful as shown by the addition of metal salts also in the denitrification phase. Phosphorus is removed from the liquid phase through a combination of precipitation, adsorption, exchange, and agglomeration and it is wasted with the primary and/or secondary sludges.

Filtration. Filtration is used in wastewater treatment as an intermediate or final polishing step for removal of SS and will also produce a reduction in BOD_5. Additional phosphorus may also be removed if the wastewater is previously treated with alum. Multi-media filter



EFFLUENT PARAMETER	MONTHLY AVERAGE LIMIT	
	NO FILTRATION	FILTRATION
BOD_5	<15 mg/L	5 mg/L
SS	<15 mg/L	5 mg/L
FECAL COLIFORM BACTERIA	200/100 ml	
pH	6.0-9.0	
NH_3-N	<1 mg/L	<1 mg/L
PHOSPHORUS AS P	1 mg/L	<1 mg/L

FIG. 7-2 TREATMENT TRAIN AND EFFLUENT CRITERIA FOR AWT—CONTINUOUS NITRIFICATION AND PHOSPHORUS REMOVAL

beds have been composed of various combinations of anthracite, sand, garnet, and activated carbon. The process may require prechlorination to prevent buildup of biological growths on stationary components of filters. Backwash systems are required and high rate filtration may require a polymer feed system to contain breakthrough.

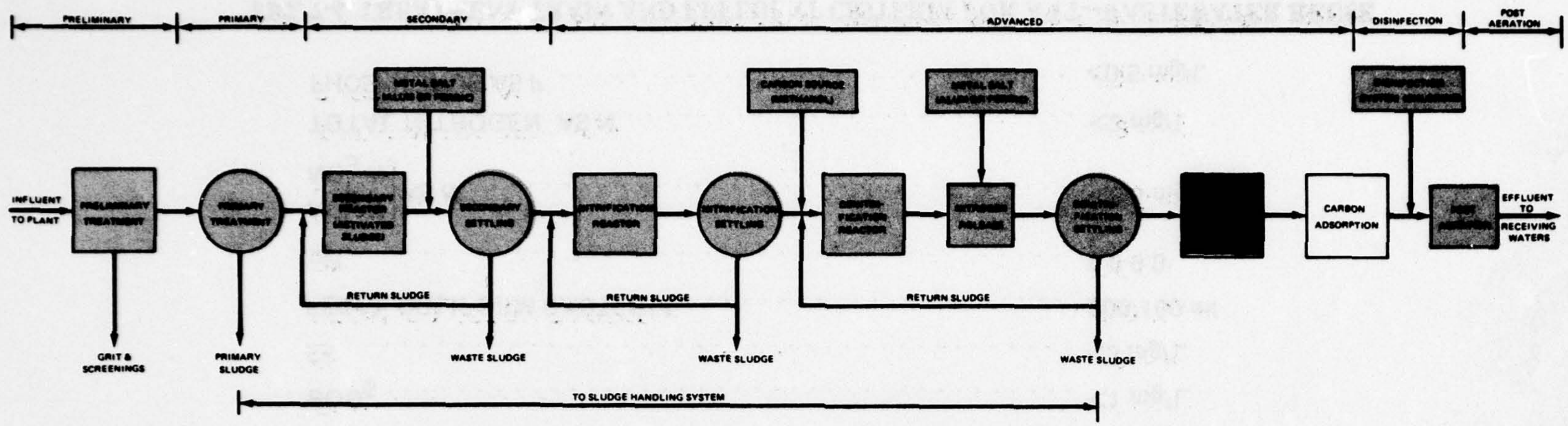
Post-Aeration. In order that the wastewater effluent not exert an immediate demand on the oxygen resources of the receiving water, the oxygen content of the wastewater effluent is increased. The processes available are hydraulic, air diffusion and mechanical. Hydraulic processes are usually a creation of cascades which require available height of fall of the effluent above the stream. Air diffusion is a process of bubbling air into the effluent through diffusers operating under compressed air. Mechanical aeration is achieved through agitation of the air-water interface.

The latter process may be combined effectively with chlorination and is used in the sizing of satellite plants.

Nitrogen Removal. Various processes are available for nitrogen removal including breakpoint chlorination, ammonia stripping, selective ion exchange, and suspended growth and fixed-film denitrification.

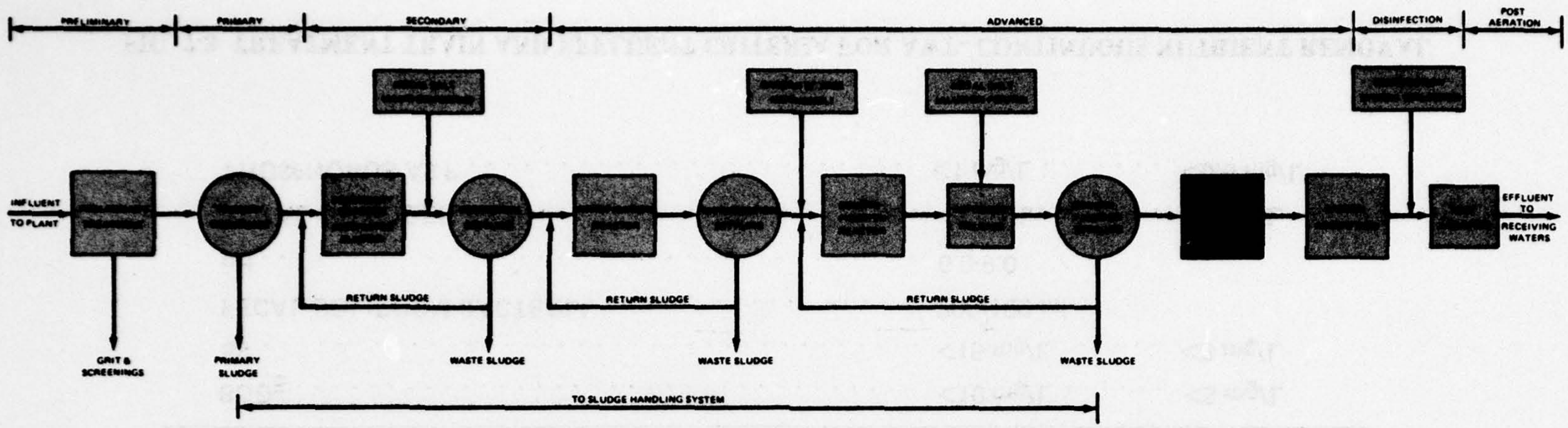
For purposes of this study, suspended growth denitrification was selected and is shown on Figure 7-3. Nitrogen in the form of nitrates can be converted to nitrogen gas by bacterial populations in the absence of oxygen. This process is carried out in a plugflow activated-sludge system following any process that converts ammonia and organic nitrogen to nitrate (nitrification). The bacteria obtain energy for growth from the nitrate-nitrogen reaction, but require an external source of carbon for all synthesis, because nitrified effluents are usually low in carbonaceous matter. Methanol is commonly used as a carbon source. Nitrogen gas formed in the denitrification reaction will hinder mixed liquor settling. Therefore, a nitrogen gas stripping reactor should precede the denitrification clarifier. Polishing of residual methanol-induced BOD_5 is an added benefit of the stripping tank.

Carbon Adsorption. Activated carbon treatment of wastewater is usually used as a final polishing process and is shown on Figure 7-4. Wastewater is passed through a columnar bed of granular activated carbon where certain soluble organics are physically and chemically adsorbed in the micropore structure of the carbon. Usually, there is



EFFLUENT PARAMETER	MONTHLY AVERAGE LIMIT	
	NO FILTRATION	FILTRATION
BOD_5	<10 mg/L	<5 mg/L
SS	<15 mg/L	<3 mg/L
FECAL COLIFORM BACTERIA	200/100 ml	
pH	6.0-9.0	
TOTAL NITROGEN AS N	<4 mg/L	<3 mg/L
PHOSPHORUS AS P	<1 mg/L	<0.5 mg/L

FIG. 7-3 TREATMENT TRAIN AND EFFLUENT CRITERIA FOR AWT—CONTINUOUS NUTRIENT REMOVAL



EFFLUENT PARAMETER	MONTHLY AVERAGE LIMIT FILTRATION
BOD_5	<1 mg/L
SS	<3 mg/L
FECAL COLIFORM BACTERIA	200/100 ml
pH	6.0-9.0
NO_2-N, NO_3-N AS N	<0.5 mg/L
TOTAL NITROGEN AS N	<3 mg/L
PHOSPHORUS AS P	<0.5 mg/L

FIG. 7-4 TREATMENT TRAIN AND EFFLUENT CRITERIA FOR AWT--WASTEWATER REUSE

biological activity within the column which aids in the removal of both soluble and suspended organic material. Filtration of SS can be achieved depending on the design of the carbon column. Backwashing facilities are needed and a regeneration system is required to remove the material adsorbed on the carbon.

Sludge Handling

Disposal of Treatment Plant Residuals. Wastewater treatment plants that provide for pollutant removals produce a significant quantity of residual material. This residual material or sludge is a semi-liquid waste which is normally processed to convert it to a suitable condition for disposal. Sludge disposal includes collection, transportation and final disposal.

The characteristics of sludge vary depending on its origin, the amount of aging that has taken place, and the type of processing to which it has been subjected. Sludge from primary sedimentation tanks is usually grey and slimy and, in most cases, has an offensive odor. Waste-activated sludge generally has a brown flocculent appearance and, when in good condition, has an inoffensive characteristic odor.

For this study, the processing and disposal of sludge from the Deer and Nut Island treatment plants is as reported in a 1973 report by Havens and Emerson Limited, Consulting Engineers, entitled A Plan for Sludge Management.

For studying various alternatives involving other plants, incineration of sludge was used as the method for disposal. For certain satellite plants, other alternatives were also investigated to show the feasibility of sludge disposal by landfilling, by regionalization and by combining with other solid wastes.

Treatment Criteria Selected

Plants with Coastal Discharges. For the Deer and Nut Island treatment plants, the process selected is in accordance with EPA (Environmental Protection Agency) minimum treatment requirements as shown on Figure 7-1. In those cases where primary treatment plus ocean outfall from the two plants is discussed, the criteria used for sizing of sedimentation basins is reduced from 1,200 to 1,000 gpd per square foot of surface area for average flows. A second criteria of 3,000 gpd per square foot for peak flow is also used.

Plants with Inland Discharges. All streams in the EMMA area are water-quality limited requiring treatment beyond secondary. Therefore, treatment requirements for inland plant discharges is based on effluent limitations established by Basin Plans being developed by the Massachusetts Division of Water Pollution Control.

Pending the findings of the Basin Plans, treatment requirements for inland plants were selected on the basis of findings under similar conditions in other locations.

The treatment selected for inland plants for the purpose of determining capital and operating costs and area requirements is shown on Figure 7-2.

In selecting the treatment requirements, consideration was given to the use of only seasonal nitrification to nitrogen removal and to the inclusion of carbon adsorption for further effluent polishing.

The Basin Plan may in the final analysis permit seasonal nitrification. However, criteria established presently in Massachusetts require all year operation of facilities whose need is established on the basis of critical dry season flows.

Nitrogen removal can be required to limit eutrophication problems and to limit the nitrate content where the receiving waters are used as a source of water supply. Since eutrophication problems are more economically and normally better controlled through the limitation of phosphorus as a nutrient, nitrogen removal for this purpose is not widely practiced. Domestic wastewaters contain nitrogen to phosphorus ratios of about 3 to 4 parts of nitrogen to 1 part of phosphorus as shown in Table 7-1. Since green and blue-green algae cells normally contain 12 to 15 parts of nitrogen to 1 part of phosphorus, domestic wastewaters contain an excess of phosphorus over that amount that these algae are able to use. This excess quantity can be utilized by certain nitrogen fixing algae in nitrogen deficient waters and this is one of the mechanisms through which excessive algae blooms can occur, resulting in an increase in the nitrogen budget. All algae, both green and blue-green thrive as long as both nitrogen and phosphorus are present. If nitrogen becomes limiting, certain species of blue-green algae can still continue to thrive as long as phosphorus is available. This situation develops in lakes and reservoirs but has not been known to exist in rivers, except possibly in backwater areas. Where phosphorus is present in excess,

most algae use nitrogen and phosphorus in a ratio of about 15 to 1 and will flourish up to ratios of 30 to 1. Before phosphorus can become limiting, the phosphorus level must be reduced to less than 0.5 mg/L when total nitrogen equals 15 mg/L or less than 1.0 if it equals 30 mg/L. Removal of nitrogen on the basis of controlling eutrophication does not appear warranted.

TABLE 7-1. TYPICAL SOURCES OF NITROGEN AND PHOSPHORUS IN AN URBAN ENVIRONMENT

Type of wastewater	Total nitrogen, mg/L as N	Total phosphorus, mg/L as P
Untreated municipal(1)	40	10
Treated municipal(1)		
Primary(1)	35	8
Secondary(1)	30	5
Combined sewage(1)	11	4
Surface runoff(1)	3	1
Rainfall(2)	1.3	.08

1. Urban Stormwater Management and Technology: An Assessment, Environmental Protection Technology Series EPA-670/2-74-040, December 1974 by Metcalf & Eddy, Inc.
2. Eutrophication: Causes, Consequences, and Correctives, Proceedings of a Symposium, National Academy of Sciences, 1969.

Unless direct water reuse is contemplated, the inclusion of carbon adsorption as a polishing technique is not warranted. Basin planning to date indicates that the oxygen resources of the stream would meet its classification in the case of contemplated plants on the Middle Charles and the Upper Neponset rivers.

CHAPTER 8

DESIGN PARAMETERS

Periods of Design

The following periods of design were used for the various components of the treatment system.

Sewers. MDC interceptors were designed for flows expected in the year 2020 when relief is required immediately or by 1980. When additional capacity is not required until the year 2000, sewers were designed for 2050 flows.

Tunnels. All tunnels were designed for flows anticipated in the year 2050.

Subaqueous Pipelines. Subaqueous pipelines were designed for flows anticipated in the year 2050.

Pumping Stations. All pumping station improvements were designed for flows anticipated in the year 2000 with the largest pump out of service.

Treatment Plants. Treatment plants and improvements to plants were sized for flows anticipated in the year 2000.

Friction Factors

Flow friction factors as used in Manning's Equation were as follows:

New Sewers

Less than 30 inches in diameter = 0.015

Between 30 inches and 84 inches in diameter = 0.013

89 inches in diameter and greater = 0.011

Old Sewers

Cast iron = 0.016

Concrete = 0.015

Brick = 0.016 except
0.014 for the South Metropolitan High Level Sewer.

Force Mains

Sizing of new force mains were based on a flow velocity of 6 fps (feet per second).

CHAPTER 9

COST PARAMETERS

General

The cost-estimating procedure described herein was generally followed in the development of the cost estimates of the various concepts and alternatives. Final estimates for the selected plan were developed using more detailed procedures.

Cost Bases

The estimated costs reflect ENR (Engineering News-Record) Index values taken at 2200 which is considered representative of costs in Boston for January 1975.

All costs include allowances for engineering and contingencies ranging from 25 percent for interceptors to 50 percent for upgrading of facilities at sewage pumping stations.

Costs for the construction of sewers, outfalls, treatment and pumping facilities that had been developed during the preparation of engineering reports for various communities involved in the study areas were used wherever applicable. In those cases, costs were updated from those presented in the reports by direct application of an ENR adjustment factor.

In other cases, the methodologies described in this chapter were used as the basis for determining costs.

Sewers

Whenever drawings were available, the length, depth and slope of the proposed sewers was taken directly from construction drawings. Relief lines were assumed to be installed parallel to the existing lines. Where construction drawings were not available, lengths were scaled from 1 inch equals 6,000 feet conceptual layout plans, and slopes and depths were estimated from the 2,000 scale USGS (U. S. Geological Survey) topo sheets.

For cost estimating purposes, two major soil conditions were established to cover the work in the study area. These two conditions are defined as follows:

Condition 1 is readily favorable for excavation based upon open cut in a dry cohesive sandy and gravelly soil. Spot sheeting or bracing is provided for trenches up to 12 feet in depth with a fully sheeted trench for depths greater than 12 feet.

Condition 2 is not readily favorable for excavation and is based on a fully sheeted trench excavation in a moderately wet ground condition.

Open cut sewer costs for these two soil conditions are shown in Tables 9-1 and 9-2.

Estimated costs include allowances for the actual cost of furnishing and installing the pipe; excavation (of which 5 percent is considered rock); trench sheeting and dewatering; backfill; installation of manholes; handling of traffic and utilities; and repaving. These tables reflect construction conditions that would be expected to occur in urban areas (i.e. utilities, resurfacing, etc.). For this reason, it was necessary to adjust the costs as shown in the tables for conditions where conduit was laid through marsh areas or in generally open and undeveloped areas. Costs for construction in open areas were taken at 80 percent of the figures shown in Tables 9-1 and 9-2, while costs in marsh areas were increased by 14 percent to allow for access problems and necessary increased dewatering activities.

Where rock excavation problems were known to exist, an additional volume of rock excavation was allowed for. The unit cost for the excavation of rock (hard granite) was taken at $100.00 per cubic yard.

Major obstructions to sewer construction considered were Routes 128, 95, 1, 9, 3, and the Massachusetts Turnpike. The lateral extent of these obstructions was scaled from the USGS topo sheets of the study area and an additional contingency factor of $100 per linear foot was applied to allow for exceptional traffic control problems and other miscellaneous items associated with such highway crossings.

Force Mains

Unit costs for the construction of the force mains associated with the various alternatives were developed for each specific instance. Due to their relatively small

TABLE 9-1 OPEN CUT SEWER COSTS FOR SOIL CONDITION NUMBER 1

1975 COSTS FOR THE EMMA AREA

AVERAGE COST IN DOLLARS PER LINEAR FOOT

DIAMETER *** (IN)	AVERAGE DEPTH IN FEET 6.	8.	10.	12.	14.	16.	18.	20.	22.	24.	26.	28.	30. ***
8	25.65	27.43	30.01	32.38	40.88	46.01	67.34	70.32	77.84	*******	*******	*******	*******
10	28.62	30.40	32.83	35.21	44.43	49.55	70.88	73.86	81.39	*******	*******	*******	*******
12	31.56	33.34	35.92	38.30	48.09	67.48	74.55	77.53	*******	*******	*******	*******	*******
15	39.56	42.66	45.84	49.11	71.76	77.36	84.63	91.98	*******	*******	*******	*******	*******
18	46.47	49.61	52.85	56.18	65.36	74.35	82.14	104.42	*******	*******	*******	*******	*******
21	57.14	60.47	63.62	67.01	72.66	81.01	88.45	96.00	124.96	135.44	144.30	152.83	163.63
24	63.08	67.03	70.23	73.69	79.41	87.41	97.10	104.89	135.83	143.84	157.14	165.80	176.74
27	68.21	71.77	74.88	78.40	84.05	92.13	102.05	109.94	144.29	152.56	165.85	174.50	185.43
30	74.28	77.46	80.77	84.20	89.93	93.62	108.67	116.94	123.18	163.54	176.94	185.73	196.81
36	85.50	88.77	94.34	100.07	105.93	111.95	118.11	131.19	139.80	148.56	196.35	214.19	225.55
42	107.80	111.15	116.84	122.69	128.70	134.87	141.22	156.36	165.19	174.19	230.15	250.27	261.92
48	*******	126.93	132.73	138.70	144.86	151.20	157.72	164.43	185.57	194.80	204.21	215.96	294.28
54	*******	130.85	136.67	142.69	148.91	155.33	161.95	190.95	200.13	223.34	232.92	244.86	257.00
60	*******	150.44	156.37	162.52	168.89	175.47	182.28	195.78	220.30	229.92	259.19	271.41	283.84
66	*******	174.89	180.94	187.22	193.74	200.49	207.48	222.33	231.95	241.81	268.02	299.95	312.67
72	*******	195.07	201.23	209.80	216.47	234.19	241.36	248.79	268.42	278.51	307.14	319.90	332.91
78	*******	*******	225.25	233.96	240.77	247.86	255.22	262.85	307.90	318.23	348.85	361.88	375.19
84	*******	*******	258.73	267.57	274.54	281.79	289.34	297.17	339.85	350.42	389.36	400.51	414.11
90	*******	*******	289.43	298.40	305.52	312.94	320.67	328.71	377.81	388.62	429.97	441.40	455.29
96	*******	*******	346.60	353.55	360.82	368.41	378.49	388.90	414.75	425.80	439.34	451.04	467.38
102	*******	*******	384.84	391.92	399.35	407.11	417.38	427.99	464.87	476.16	489.96	501.94	518.58
108	*******	*******	*******	435.99	443.57	451.51	461.96	472.78	514.20	525.74	539.80	552.06	568.99
114	*******	*******	*******	475.31	482.33	490.44	499.65	510.68	551.60	564.10	578.42	591.68	465.64
120	*******	*******	*******	519.01	526.90	536.62	548.18	559.42	596.97	611.16	625.74	638.56	656.10
126	*******	*******	*******	566.23	573.55	584.17	598.81	609.53	648.03	662.47	677.31	691.13	709.69

TABLE 9-2 OPEN CUT SEWER COSTS FOR SOIL CONDITION NUMBER 2

1975 COSTS FOR THE EMMA AREA

AVERAGE COST IN DOLLARS PER LINEAR FOOT

DIAMETER *** (IN)	A V E R A G E D E P T H I N F E E T 6.	8.	10.	12.	14.	16.	18.	20.	22.	24.	26.	28.	*** 30.
8	49.41	64.01	78.54	92.86	113.60	129.53	164.97	181.92	209.60	*******	*******	*******	*******
10	52.38	66.83	81.50	95.69	117.15	133.07	168.80	185.46	213.15	*******	*******	*******	*******
12	55.32	69.92	82.29	98.78	120.81	151.00	172.47	189.13	*******	*******	*******	*******	*******
15	63.32	79.38	95.52	109.59	144.48	160.88	182.40	203.72	*******	*******	*******	*******	*******
18	70.23	86.33	102.53	116.66	138.08	158.01	179.91	216.16	*******	*******	*******	*******	*******
21	80.90	97.19	112.14	127.49	145.38	164.53	186.23	207.74	261.90	297.30	329.92	364.95	388.55
24	87.42	103.61	118.76	134.17	152.13	173.23	194.88	216.49	272.77	330.46	342.76	385.11	401.38
27	92.25	108.35	123.98	138.73	157.06	178.09	199.54	220.82	280.80	326.80	351.46	386.32	410.07
30	98.04	114.18	130.45	144.68	163.37	180.02	205.87	227.10	259.26	325.53	362.70	397.41	421.45
36	109.26	125.49	141.86	158.39	175.05	194.03	215.31	243.51	278.04	310.56	427.47	425.87	450.19
42	131.56	147.87	164.36	181.01	197.82	216.95	238.42	268.68	303.43	336.19	418.07	461.95	474.75
48	*******	163.65	180.25	197.02	213.98	233.28	254.92	276.75	323.81	356.80	392.13	427.64	508.27
54	*******	167.57	184.19	201.01	218.03	237.41	259.15	303.27	334.05	385.34	420.84	456.54	481.64
60	*******	187.16	203.89	220.84	238.01	257.55	279.48	308.10	358.54	391.92	447.11	483.08	508.48
66	*******	211.61	228.46	245.54	262.86	282.57	304.68	334.65	370.19	403.80	455.94	511.63	537.31
72	*******	231.79	248.75	268.12	285.59	316.27	338.56	361.11	406.66	440.51	495.06	531.58	557.55
78	*******	*******	272.77	292.28	309.89	329.94	352.42	375.17	446.14	480.23	536.77	573.56	599.83
84	*******	*******	306.25	325.89	343.66	363.87	386.53	409.49	478.09	512.42	577.28	612.19	638.75
90	*******	*******	336.95	356.72	374.63	395.02	417.87	441.03	516.05	550.62	617.89	653.08	679.93
96	*******	*******	391.96	411.87	429.94	452.65	475.69	501.22	552.99	589.96	627.26	667.04	694.18
102	*******	*******	417.24	450.24	468.47	491.35	514.58	540.31	603.11	640.32	677.88	717.94	745.38
108	*******	*******	*******	494.31	512.69	535.75	559.16	585.10	652.44	689.90	727.72	768.06	795.79
114	*******	*******	*******	533.64	554.33	577.56	599.01	625.16	697.04	743.38	781.46	819.92	852.28
120	*******	*******	*******	577.33	596.02	621.58	645.38	671.74	735.21	753.72	813.66	854.56	882.90
126	*******	*******	*******	621.67	646.99	670.57	694.57	721.13	806.43	857.59	896.19	933.05	966.01

cost and the few instances in which force mains had to be estimated, their cost was added to the pumping station costs, wherever such were necessary.

Submarine Outfalls and River Crossings

Costs of submarine outfalls were updated from various engineering studies wherever possible. In those cases where reports were not available for possible new satellite plants on the coastline, outfall costs were based on a length of 1,800 feet using the costs reflected on Figure 9-1.

These unit costs are based on an evaluation of known costs of submarine outfalls constructed in areas with generally similar oceanographic characteristics to those here considered, and reflect costs for outfalls constructed on piles and terminating in a moderate depth of approximately 60 feet. Estimated costs include allowances for the actual cost of the pipe plus a straight diffuser at the outlet end; excavation associated with the installation of the pipe; pipe laying; piles and backfill.

The costs associated with major river crossings in tidal areas were also determined based on submarine outfall construction practices and, consequently, Figure 9-1 was used in their analysis.

For inland river crossings, costs were based on figures shown in Tables 9-1 and 9-2 plus an allowance of $100 per foot to allow for the construction and removal of a working surface and miscellaneous construction difficulties anticipated at the crossings.

Tunnels

Tunnels were used in all instances where the depth of the proposed interceptor exceeded 30 feet or was in an extremely congested area. Costs were developed for each specific instance and were based on a "shooting and quarry" technique normally used in areas of hard rock. Costs include the necessary labor, equipment, and materials associated with tunnel work and are based on a three-shift operation with a tunneling rate of 9 feet per 24-hour day. The costs also include the access and air-vent shafts and are based on operating in a free air surface at the tunnel face.

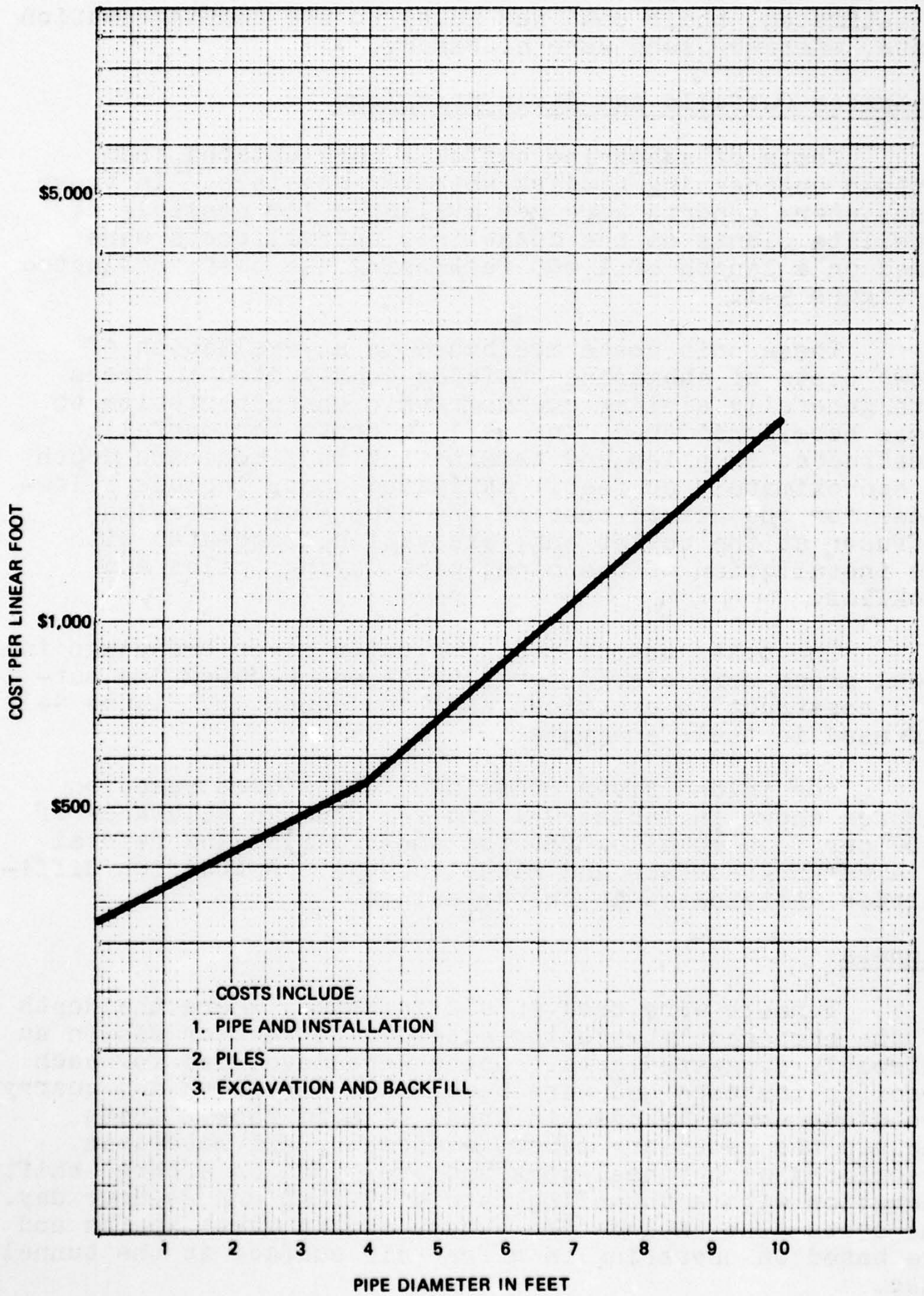


FIG. 9-1 SUBMARINE OUTFALL COSTS

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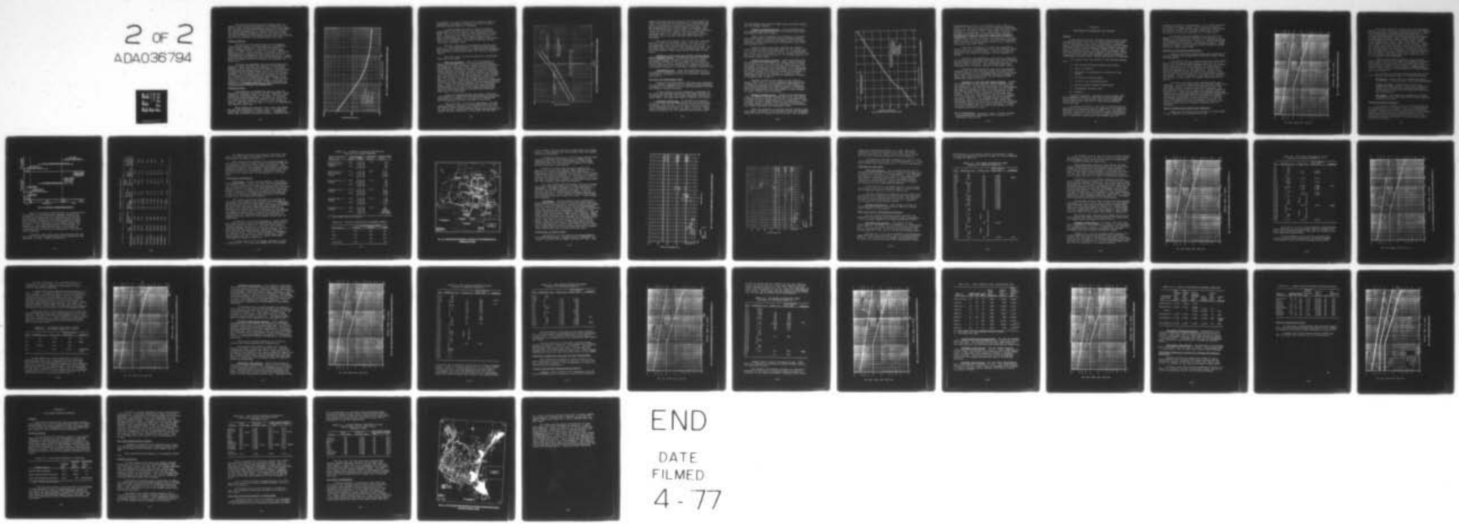

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For short tunnel projects involving relief of sewers, this overall cost amounted to between \$5.3 and \$6.3 million per mile depending on size, depth and length. For the major alternative of ocean disposal of Deer and Nut Island treatment plants effluent, the tunnel cost, excluding pumping facilities and the diffuser, was \$5.3 million per mile for Inner Harbor tunnels and \$10.6 million per mile for tunnels in the Massachusetts Bay area.

Pumping Stations

The costs for the construction of new pumping stations were based on detailed analyses performed for other pumping facilities. The costs are based on a depth of substructure of 30 feet and a total dynamic head of 60 feet. Costs include the structure; pumps and appurtenances; piping and valves; electrical work and instrumentation; comminutors and engine generators. Costs in dollars per mgd capacity based on maximum plant capacity with the largest unit out of service are presented on Figure 9-2.

The cost for upgrading the existing Metropolitan District pumping stations are based on a case-by-case analysis. Such costs include replacement of existing pumping stations where required or for the necessary work to modernize and automate those facilities that can be upgraded. The estimated costs also include an allowance of 50 percent for engineering and contingencies but do not provide for land acquisition, right-of-ways, legal fees, and interest during construction. A detailed discussion of each of the concerned pumping facilities is contained in Technical Data Vol. 9, MDC Interceptor and Pumping Station Analysis and Improvements.

Treatment Plants

Determination of generalized capital costs for wastewater treatment facilities is most frequently accomplished by utilizing actual construction cost data from previously constructed plants. In order for the data to be useful over a range of treatment plant sizes, the cost data usually takes the form of one or a series of curves. Each curve is the result of a plot of construction cost against plant size.

When estimating treatment plant costs, one method has been the practice to develop a plot of a series of points each representing a single plant. Although the plants may not employ treatment processes consistent with

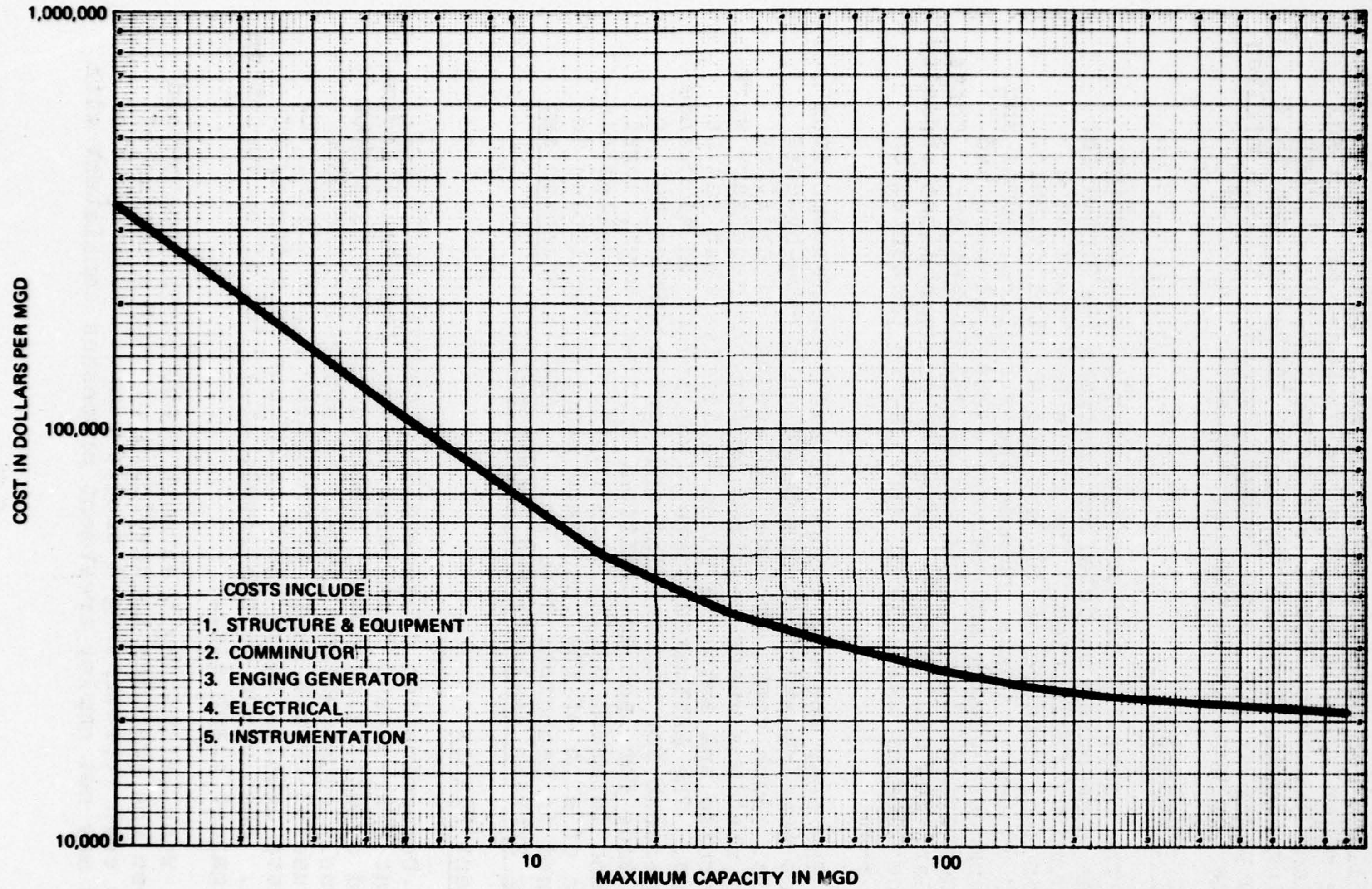

FIG. 9-2 SEWAGE PUMPING STATION CONSTRUCTION COSTS

one another, the plot of points and resulting curve is considered to generally represent the cost of plants having a similar degree of treatment.

A second method has been to break the actual construction cost data down a unit process basis and relate the cost to a selected design parameter for each unit. Given a design quantity, the costs of all units may be determined, or, for a range of quantities, a curve may be developed. This method permits total plant cost to be estimated on the basis of the size of the individual treatment units.

Thirdly, costs may be estimated by applying unit prices to a detailed breakdown of materials and labor. This method of estimating is used when detailed estimates are conducted during final stages for facility implementation.

For this study, the second method for estimating plant costs was used.

Basis of Estimate. Curve "A" as presented on Figure 9-3 considers costs for preliminary treatment, including grit and screenings removal; primary treatment and secondary treatment; while Curve "B" also reflects nitrification; filtration; reaeration and disinfection. Sludge disposal facilities include flotation thickening of waste-activated sludge vacuum filtration and incineration for plants of 15 mgd and larger; and vacuum filtration and incineration for plants between 10 mgd and 149 mgd. For plants of less than 10 mgd, solids will be disposed to land. Phosphorus removal will be accomplished by metal salt addition upstream of the secondary settling tank. Costs for influent pumping and for intermediate pumping ahead of the filters have also been included. The processes for various sized plants represent what would be considered typical cost-effective processes based upon our experience.

Costs for outside piping, site work, electrical instrumentation, operations and administrative facilities along with an allowance of 35 percent for engineering and contingencies has been included in the total.

The first step of the curve development involved sizing treatment units for the aforementioned processes for plants having average daily flows of 2, 5, 10, 15, 25, and 35 mgd. These sizes were chosen because satellite plants (with the exception of Watertown) are included

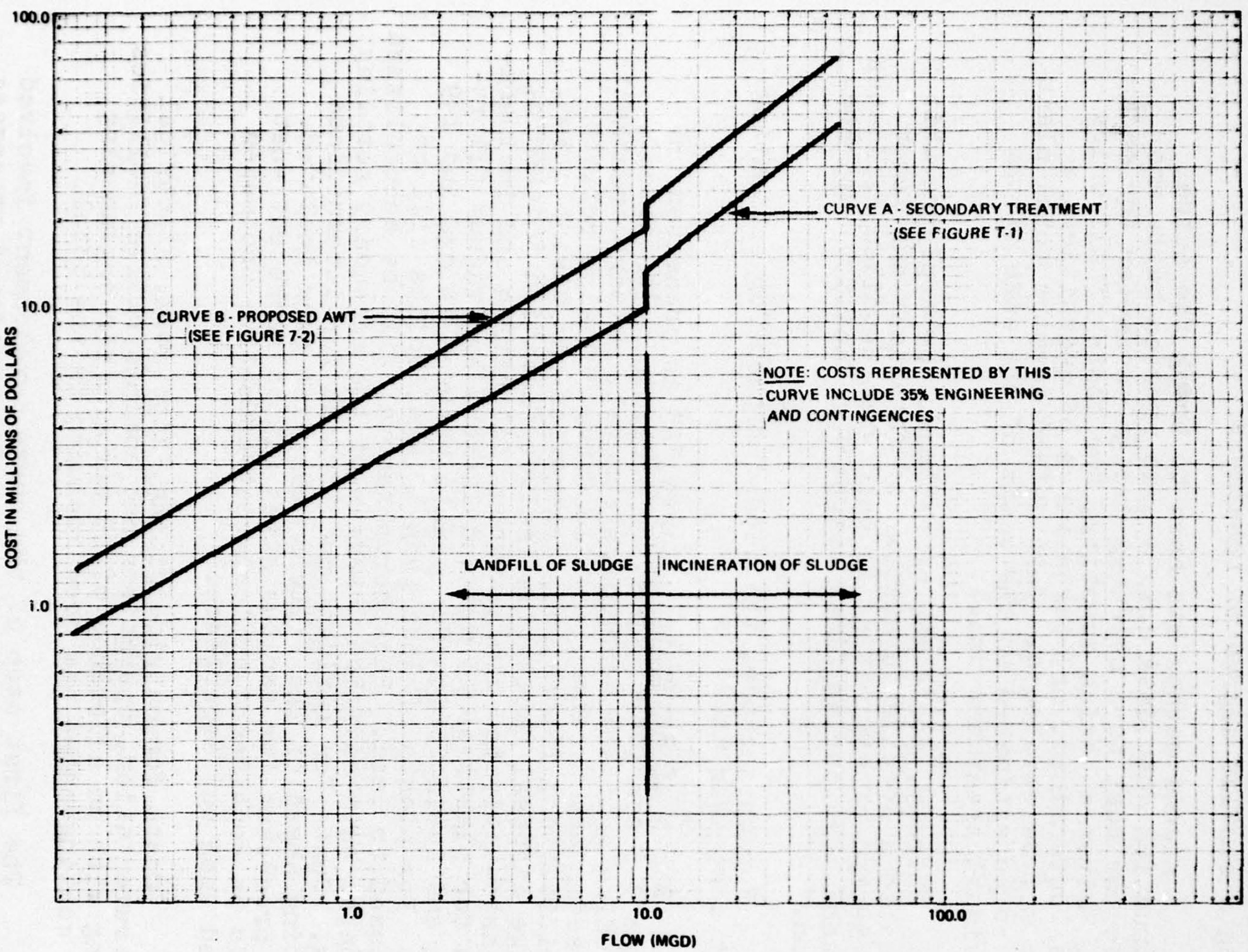

FIG. 9-3 WASTEWATER TREATMENT PLANT CONSTRUCTION COSTS

within its range and the sizes are at points within the range which will permit development of a representative curve. Concurrently, historical construction cost data was being reviewed and broken down by unit type. Data was evaluated by unit size in order to establish cost trends for differently sized units, e.g., small treatment units generally have a higher unit cost than larger treatment units. In addition, when applicable, actual treatment unit costs were utilized where they were available.

Following development, each of the unit costs was applied to each of the sized units. The total cost of the component units was then plotted for each of the selected sizes and a curve drawn linking the points. The resulting curve, Figure 9-3, then provided the cost for any like treatment plant sized within the range of the curve.

Upgrading of Existing Deer and Nut Islands Wastewater Treatment Plants. A detailed discussion relating to the upgrading of the existing Deer and Nut Island wastewater treatment plants is presented in Technical Data Volumes 10 and 11, respectively, together with discussion relating to the expansion of primary facilities and ultimate extension to secondary treatment capabilities.

Recommended Plan. Costs for facilities in the recommended plan were not taken from Figure 9-3 but were developed by estimating the cost of each major component specifically.

Operation and Maintenance Costs

Operation and maintenance costs have been developed for the various components of the system and are presented separately for treatment plants, existing pumping stations, and proposed pumping stations.

A brief section is also presented to describe how the total MDC Sewerage Division's 1975 Budget Request was incorporated into the total annual operation and maintenance costs. All costs are based on January 1975 prices.

Transport Facilities. No estimate was prepared to reflect the cost for maintaining the new interceptors proposed in this report. It was felt that any new pipes could reasonably be expected to remain virtually maintenance free during the first few years of service. Maintenance allowances for the existing interceptors within

the MDC System were based on those funds allocated within the 1975 budget request.

Proposed Pumping Stations. Cost associated with the operation and maintenance of the proposed facilities were based on EPA cost curves.

Labor rates associated with operation and maintenance were based on actual pay rates currently used by the MDC, to which 25 percent was added to reflect allowances for fringe benefits such as retirement, sick leave and holidays, etc.

Electric power costs were computed for various sized pumping stations and were taken at the current rate of 2.2 cents per kwh (kilowatt-hour). All other material and supply costs were based on the EPA curves updated to an ENR of 2200 and relate directly to the average quantity of wastewater pumped (mgd).

Existing Pumping Stations. Costs associated with the operation and maintenance of sewage pumping stations varies widely with the flow, type of power used to drive the pumps, the age of the facilities, and the degree of automation incorporated into the design of the facilities. The estimated operation and maintenance costs associated with these pumping facilities are based on the manner of operation that would be required as a result of any improvements made to the stations as described in detail in Technical Data Volume 9.

Manpower estimates were based on the sizes of actual staffs used at similar existing pumping stations. Although all stations were automated to some degree, in no cases were manpower requirements totally eliminated. Power costs were based on a rate charge of 2.2 cents per kwh while maintenance costs were based on actual experience with similar sized facilities.

- Sewage Treatment Plant. Operation and maintenance costs for sewage treatment plants vary widely and depend primarily upon the quality of effluent to be achieved and the means by which sludge disposal is accomplished. Plant location, operator capabilities and the characteristics of sewage being treated are also important considerations that effect operation and maintenance costs.

With the exception of the Deer and Nut Island treatment plants, operation and maintenance costs were estimated using the curve on Figure 9-4 which reflects the operation

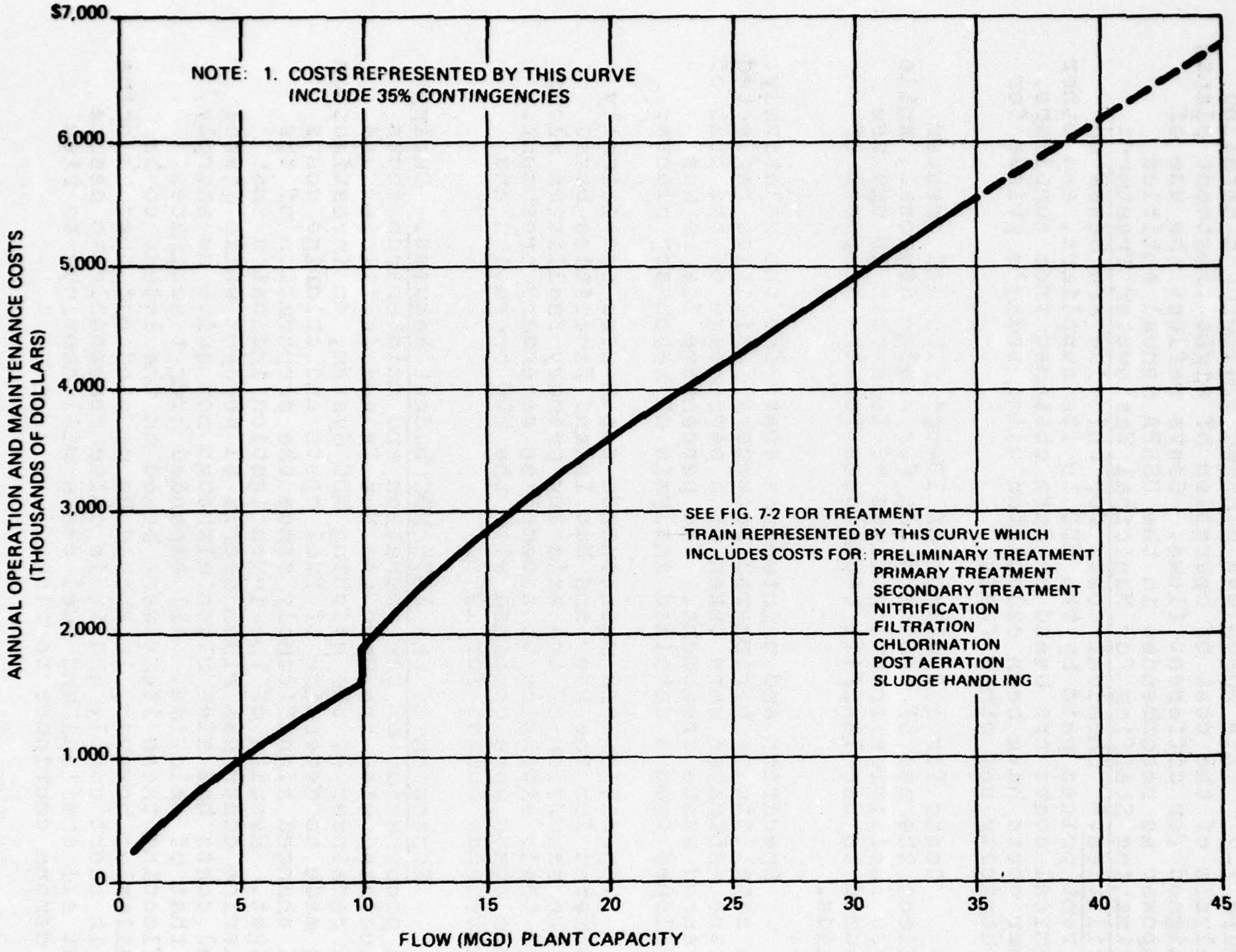

FIG. 9-4 OPERATION AND MAINTENANCE COSTS ADVANCED WASTE TREATMENT

and maintenance costs of the treatment train shown on Figure 7-2. This curve was plotted following a detailed analysis of the cost of operation of eight treatment plants designed for different flows. Costs reflect the use of manpower as recommended in the USEPA manual entitled Estimating Staffing for Municipal Wastewater Treatment Facilities.* Chemical costs for chlorine are based on current prices paid by the MDC to its suppliers, and other chemical costs are based on data obtained from suppliers. Power costs have been calculated using today's prices for electricity and other fuels.

Costs for all plants of 10-mgd flow and greater reflect the use of incineration for sludge disposal, while those facilities treating flows of less than 10 mgd are assumed to use landfill techniques for the disposal of solids.

Operation and maintenance costs for the relatively few satellite or peripheral secondary facilities reflected in the estimates were taken at a percentage of the cost of advanced waste treatment. The percentage figure was developed from a detailed analysis of secondary plants.

Operation and maintenance costs were specifically estimated for the Deer and Nut Island facilities based on the expansion of the existing primary facilities along with their extension to accomplish secondary treatment. These costs were combined with the MDC operation and maintenance budget for 1975.

Expansion of the 1975 MDC Budget Request. During the preparation of the operation and maintenance costs associated with the Deer and Nut Island facilities and the remainder of the existing MDC System, an investigation was made to determine if fuel costs and chlorine costs had changed significantly since the preparation of the budget. Results of the investigation indicated that chlorine costs had risen nearly 51 percent while diesel fuel costs had also risen although not quite as sharply as that of chlorine. All expanded budget estimates reflecting these items were based on the latest costs available; however, it should be pointed out that chlorine is in short supply and it is quite reasonable to assume that all chemical and fuel costs will continue to rise as demand continues to rise.

*U. S. Environmental Protection Agency, Office of Water Program Operations, Washington, D.C., Contract No. 68-01-0328, March 1973.

APPENDIX A

INFILTRATION MEASUREMENTS AND ANALYSIS

General

Infiltration is water entering a sewer system including service connections from the ground through such means as defective pipes, pipe joints, connections, or manhole walls. Infiltration does not include inflow, which is water discharged into a sewer system including service connections from such sources as roof leaders, cellar, yard, and area drains, foundation drains, cooling water discharges, drains from springs and swampy areas, manhole covers, cross connections from storm sewers and combined sewers, catchbasins, stormwaters, surface runoff, street wash waters, or drainage.

For a given area, the amount of infiltration depends upon:

1. Type of and distance between pipe joints;
2. Age of the sewer;
3. Elevation of groundwater in relation to the sewer;
4. Proximity to watercourses;
5. Nature of the surrounding soil;
6. Quality control during installation;
7. Topographic features; and
8. Climate.

Spring is generally considered the wet season when the groundwater levels are high due to melting snow and heavy rains, while later summer and fall are considered the dry season when rainfall is light and groundwater levels are low.

In design of sewers, a peak rate of infiltration is used which is generally based on a measure of the condition and size of the tributary sewer system. For the design of treatment facilities, both a peak and average infiltration value is necessary. The peak value is used for determination of hydraulic capacity and the average value for

treatment component determinations. It is common practice to provide for higher rates of infiltration allowances for sizing of sewers serving small areas than larger areas in order to account for the lower probability of high infiltration occurring uniformly over a large area.

To evaluate the peak sewage flow rates for the analysis of existing sewer systems or the design of new sewers, it is necessary to account for a reasonable amount of unavoidable infiltration. Figure A-1 shows traditional peak infiltration allowances for designing sewers. These curves are based on past experience with sewerage systems similar to those under study.

Purpose of Infiltration Measurements

Limited infiltration measurements were conducted to further evaluate the suitability of general design curves for this study.

Infiltration can be a serious problem in many sewerage collection systems particularly those over 30 or 40 years old. The Metropolitan Sewerage District was created by the legislature in 1889; however, the first Boston sewer was built prior to 1700 making the oldest part of Boston's sewerage system 275 years old. At that time, all sewers were built by private parties which, in many cases, were the householders on the street where the sewer was needed. Thus, in addition to the age of the sewers, the quality of workmanship to minimize infiltration is a factor.

In 1884-5, the Boston Main Drainage System was completed. It served Charlestown, East Boston, Somerville, Cambridge, Everett, Chelsea, and Winthrop in the north and Boston Proper, Brookline, Roxbury, Dorchester, and South Boston in the south. Thus, this original system is 90 years old. Since the Metropolitan Sewerage System now serves over 130,000 sewered acres including 43 communities, there is an even greater need to allocate infiltration allowances on the basis of type of system. It was felt that field measurements are necessary to show how the curves on Figure A-1 should be modified for use in this study or that possibly a further breakdown would be necessary.

Basis for Establishing Sewer Age Categories

Early in the study, it was decided to group sewers in each community in accordance with age.

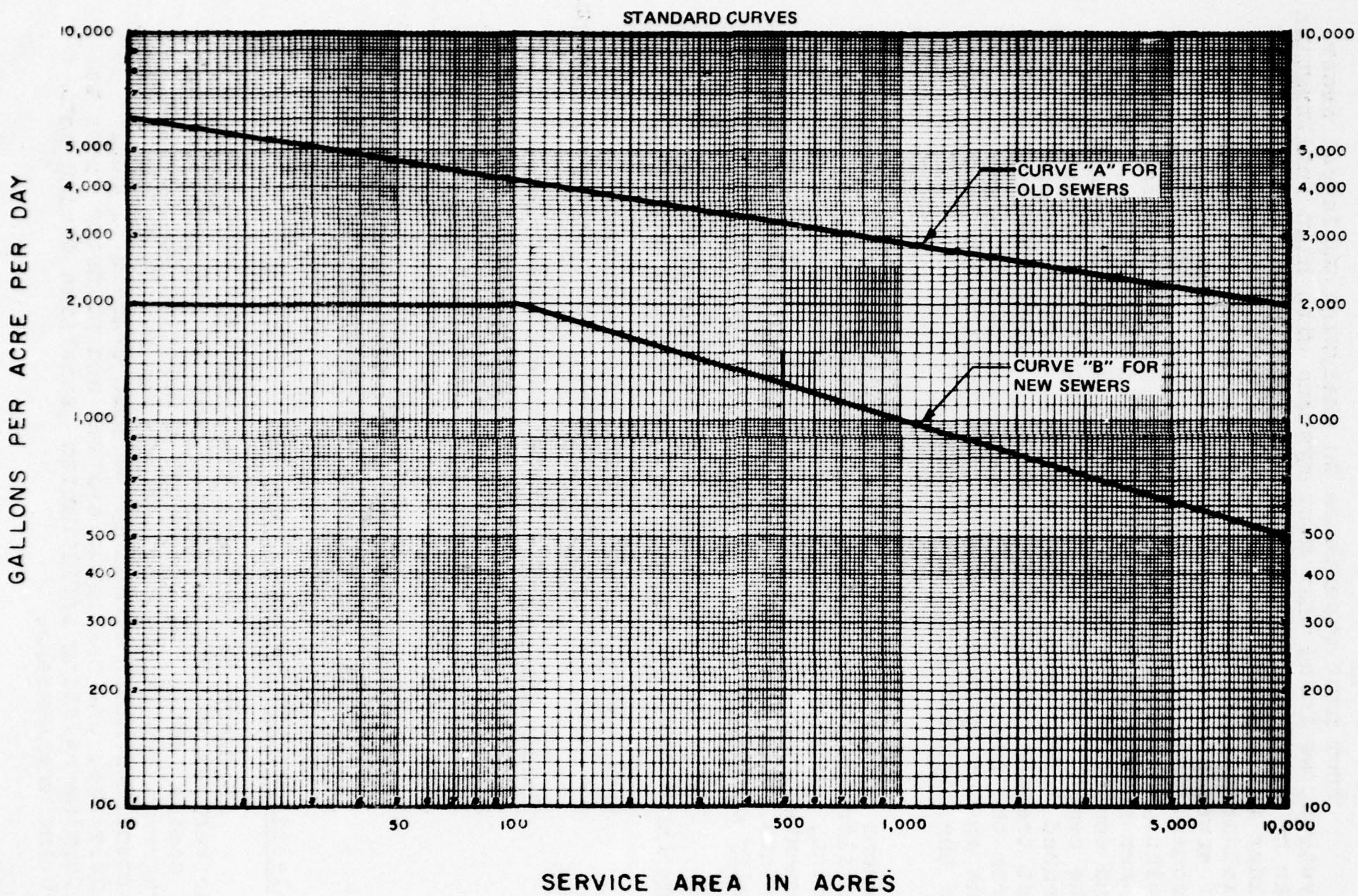

FIG. A-1 TYPICAL DESIGN PEAK INFILTRATION RATES

From past experience in analyzing municipal sewer systems, we found that most systems with high infiltration can be attributed to breaks and leaky pipe joints. The older the system, the greater the infiltration. To explain this phenomenon, we investigated the chronology of sewer pipe jointing. Pipe joint construction was accomplished with open joints, mortar joints, cement joints, and poured joints. Open joints were used for storm sewers in dry ground close to the surface. Mortar and cement joints were commonly used on all sewers with the cement joint being the more watertight of the two. Poured joints were, and still are, used occasionally in wet trenches where it is necessary to exclude groundwater from the sewer. However, today most of the pipe laid has an O-ring rubber gasket-type joint which is felt to be the tightest joint available.

From an infiltration standpoint, the open and cement mortar joints would permit the highest groundwater infiltration into the pipe, the hot-poured bituminous joint, being a flexible joint, would be tighter than the cement-mortar joint but not as tight as rubber-gasket joints. The history of jointing methods is shown graphically on Figure A-2.

As a result of this, we have developed the following three age categories based on jointing techniques:

Old Sewers - Sewers that were constructed prior to 1940 when cement-mortared joints were predominant.

Middle Age Sewer - Those sewers constructed between 1940 and 1959 when hot-poured bituminous joints for vitrified-clay pipe and flat-ribbed rubber-gasket joints for reinforced-concrete pipe were predominant.

New Sewers - New sewers are designated as those constructed after 1959 when push-on rubber gaskets started to be used.

Selection of Meter Locations

In order to estimate the rate of infiltration for the various systems as further data to the establishment of design curves, we undertook a metering and testing program. The purpose of the program was to select several communities which contained various degrees of old, middle age, and new sewer systems and to meter flows to determine existing infiltration quantities during both wet and dry seasons.

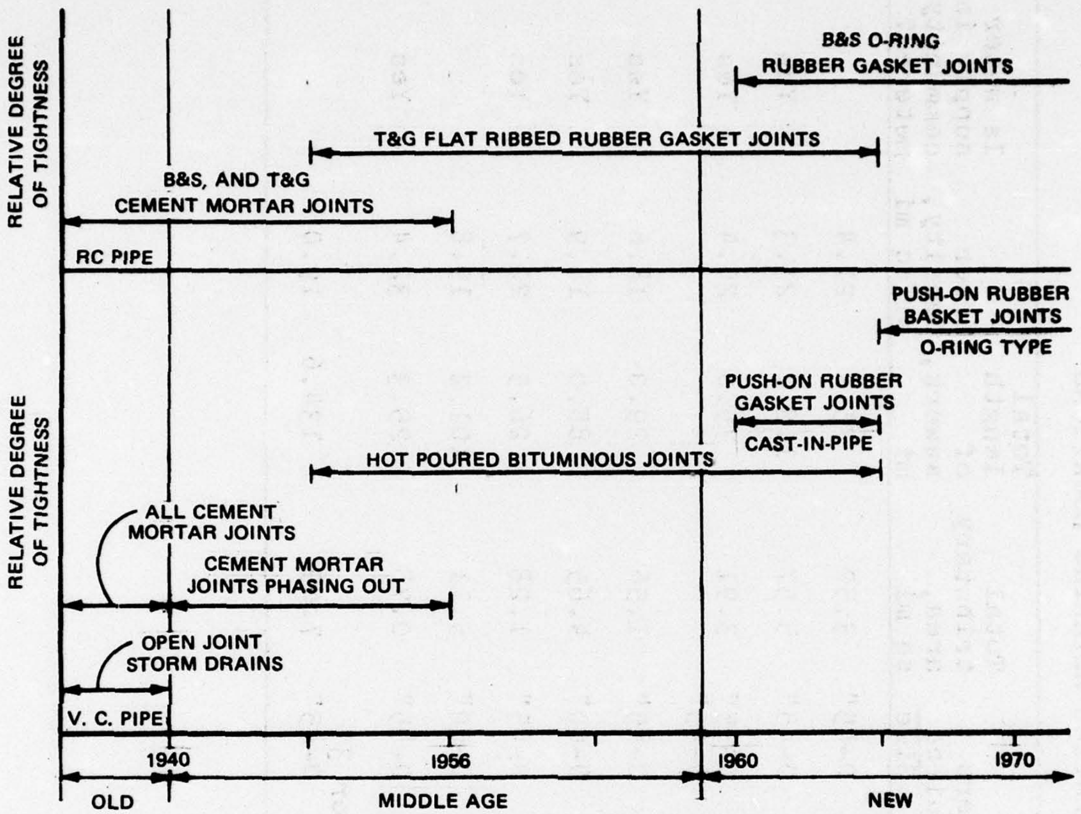

FIG. A-2 HISTORY OF SEWER PIPE JOINTING

Prior to the meter installations, the entire collection system of the Metropolitan Sewerage District was reviewed to determine the most desirable locations for the metering recognizing the limited resources allowed. The perimeter communities were favored because in many cases, an entire community could be metered with one or two meters. If a community in the "inner suburbs" was metered, it would have required six or more meters to obtain the total community flow due to the number of connections made to the major interceptor in that particular community.

Initially, nine communities were selected from the south and the north systems and pertinent information was developed for each as shown in Table A-1.

TABLE A-1. POTENTIAL METERING LOCATIONS

Municipality	MSD area	Predominant system age	Meters required No.	Meters required Size	Total tributary area, sq mi	Total length of sewers, mi	Sewer density, mi/sq mi	Is water supply in community metered?
Belmont	North	Old	(2)	0-45"	3.52	75.2	21.4	
Lexington	North	New	(2)	0-45"	5.57	118.7	21.3	Yes
Wakefield	North	Old	(1) (1)	0-15" 0-45"	3.91	79.6	20.4	Yes
Randolph	South	New	(1)	0-45"	1.56	29.0	18.6	Yes
Burlington	North	New	(1)	0-60"	4.65	88.0	18.9	Yes
Westwood	South	New	(1)	0-45"	1.28	26.5	20.7	Yes
Weymouth	South	New	(3)	0-60"	5.11	101.2	19.8	
Stoughton	South	M.A.	(1)	0-45"	0.78	25.3	32.4	Yes
Waltham	North	Old	(2 or 3)	0-45"	7.09	134.6	19.0	

Following a detailed evaluation of the above location, six communities or portions thereof were selected for metering as shown on Figure A-3.

The criteria for selection of an area was based on the ability to meter an area of over 100 acres in size and to accomplish this with as few meters as possible. The communities selected were Wakefield, Burlington, Lexington, Westwood, Stoughton, and Randolph. These communities were used as the basis for determining infiltration rates for typically old, middle age, and new systems in the study area.

Infiltration Measurements

Wet Season. The wet season (spring) infiltration measurements began on April 25, 1973 with the installation of a 15-inch "bubble pipe" type meter on a 12-inch trunk line in Greenwood Street at the Melrose-Wakefield town line. Between April 25 and April 28, there were five additional meters installed on various trunk lines serving the communities of Wakefield, Lexington, Westwood, and Stoughton. On May 8, an additional meter was installed on the Winn Street trunk line leaving Burlington.

The meters, which were operated for a minimum of two weeks, were checked every 24 hours at which time new charts were installed and the "bubble pipe" or "diaphragm", which extended into the liquid flow, was cleared of debris. The daily flow variations obtained were studied and a minimum early morning flow was calculated for each day. The number of acres tributary to the meter was ascertained from sewerage system maps. Using this information, an infiltration rate charge was plotted and the range of minimum flows was shown and the average minimum flow was identified.

In addition to the flow measurement, "grab samples" were taken at each location during peak and minimum flow periods as shown in Table A-2. The peak flows usually occurred between the hours of 10:00 a.m. and 2:00 p.m., while the minimum flows usually occurred between 2:00 a.m. and 6:00 a.m. The samples were tested for BOD_5, pH, SS, and chlorides. The test results helped to determine the portion of early morning flows consisting of infiltration when they were compared to typical wastewater concentrations shown in Table A-3.

Of prime concern was the sewage strength in terms of BOD_5 and SS. If a very weak sewage was found during

TABLE A-2. LOCATION OF SAMPLING STATIONS AND TIME AND FLOW DURING SAMPLING

Meter location, pipe size	Grab sample Date	Grab sample Time	Capacity, cfs(1)	Actual flow, cfs(1)
Wakefield No. 1	5/23	2:50 am	1.5	.31
Greenwood St.		11:30 am		.41
(12"Ø)	5/31	3:30 am		.19
		11:00 am		.24
Wakefield No. 2	5/23	2:45 am	25.8	9.21
B&M Railroad		11:00 am		13.21
(30"Ø)	5/31	3:30 am		7.64
		11:15 am		11.87
Burlington No. 3	5/23	4:00 am	9.6	.43
(24"Ø)		12:50 pm		.81
	5/31	2:30 am		.72
		2:30 pm		1.09
Lexington No. 4	5/23	3:25 am	16.5	7.51
(33"Ø)		12:15 pm		8.50
	5/31	3:00 am		5.68
		12:30 pm		7.36
Westwood No. 6	5/23	4:30 am	10.0	.70
(30"Ø)		2:15 pm		1.06
	5/31	4:15 am		1.42
		3:45 pm		1.34
Stoughton No. 7	5/23	5:50 am	6.6	NO
(20"Ø)		2:50 pm		FLOW
	5/31	5:15 am		RECORDS
		3:50 pm		AVAILABLE

1. cfs = cubic feet per second.

TABLE A-3. TYPICAL COMPOSITION OF DOMESTIC SEWAGE

Constituent	Concentration, mg/L Strong	Medium	Weak
SS	350	200	100
BOD_5	300	200	100
pH	6.0	7.2	8.0
Chlorides	100	50	30

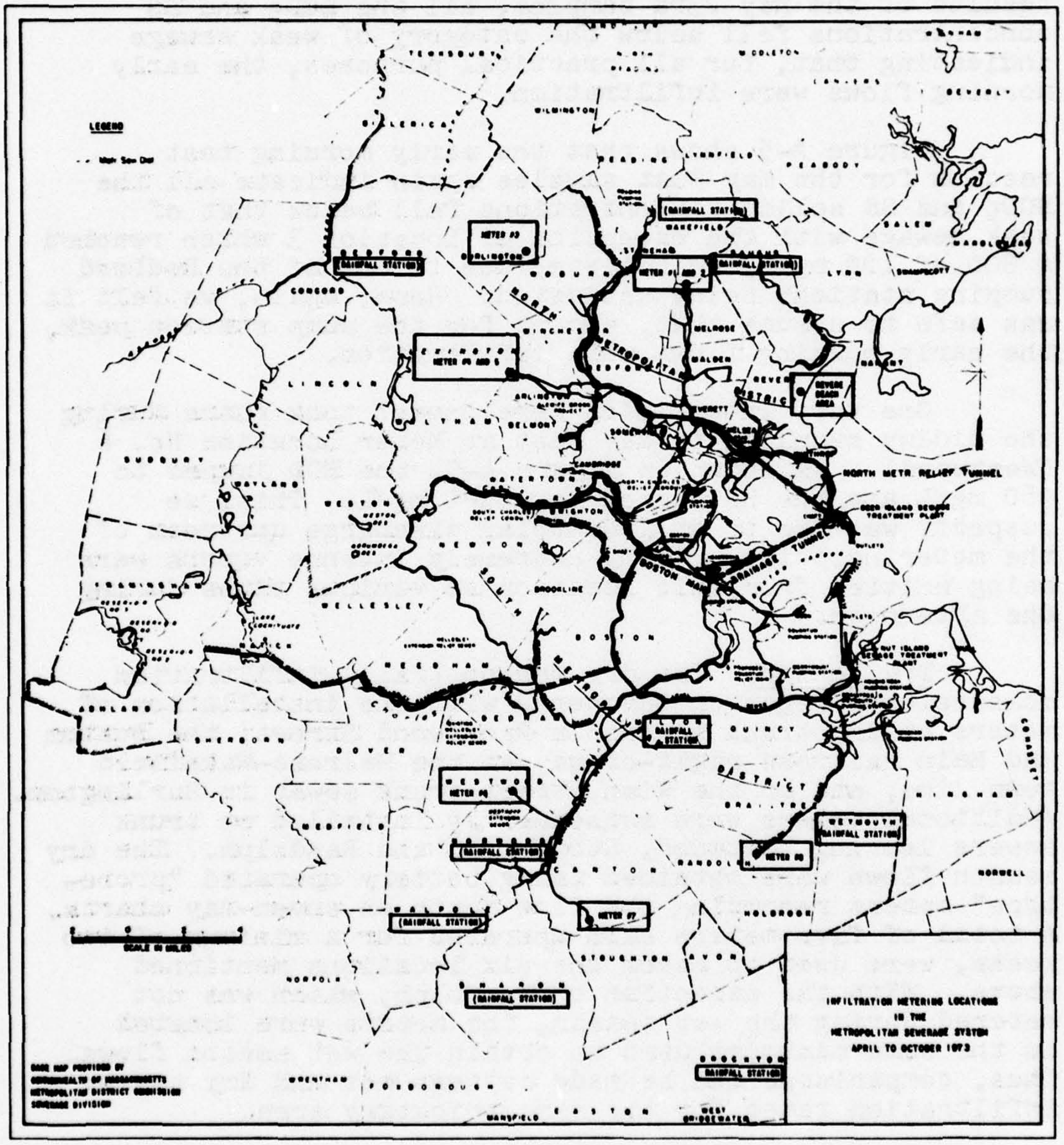

FIG. A-3 INFILTRATION METERING LOCATIONS IN THE METROPOLITAN SEWERAGE SYSTEM

early morning flow when testing for the above two constituents, it was assumed that the minimum flows were almost entirely infiltration.

As shown on Figure A-4, for the early morning test results of the May 23rd samples, all the BOD_5 and SS concentrations fell below the category of weak sewage indicating that, for all practical purposes, the early morning flows were infiltration.

Figure A-5 shows that the early morning test results for the May 31st samples again indicate all the BOD_5 and SS solids concentrations fell below that of weak sewage with the exception of Location 3 which reached a BOD of 100 mg/L, we believe, due to one of the Bedford pumping stations being activated. Here, again, we felt it was safe to assume that, except for the pump station peak, the early morning flows were infiltration.

One very interesting development took place during the midday sampling on May 31st at Meter Location No. 6 (Westwood). As shown on Figure A-5, the BOD jumped to 960 mg/L and the SS jumped to 1,320 mg/L. This, we suspect, was due to an industrial discharge upstream of the metering point. Also, extremely intense vapors were being emitted from this location at various times during the afternoon.

Dry Season. The dry season (fall) infiltration measurements began on October 2 with the installation of meters on the trunk sewers in Greenwood Street; the Boston and Main Railroad right-of-way at the Melrose-Wakefield town line; and on the Winn Street trunk sewer in Burlington. Additional meters were subsequently installed on trunk sewers leaving Westwood, Stoughton, and Randolph. The dry season flows were obtained using battery operated "probe-type" meters recording the flow depth on seven-day charts. A total of five meters each operated for a minimum of two weeks, were used to cover the six locations mentioned above. With the exception of Randolph, which was not metered during the wet season, the meters were located in the same manholes used to obtain the wet season flows. Thus, comparisons can be made between wet and dry season infiltration rates for the same tributary area.

Method Used to Compute Flows

Essentially, all the depth-of-flow measurements were made using either a "bubble pipe", "diaphragm", or "probe" type meter which senses the depth of flow. This

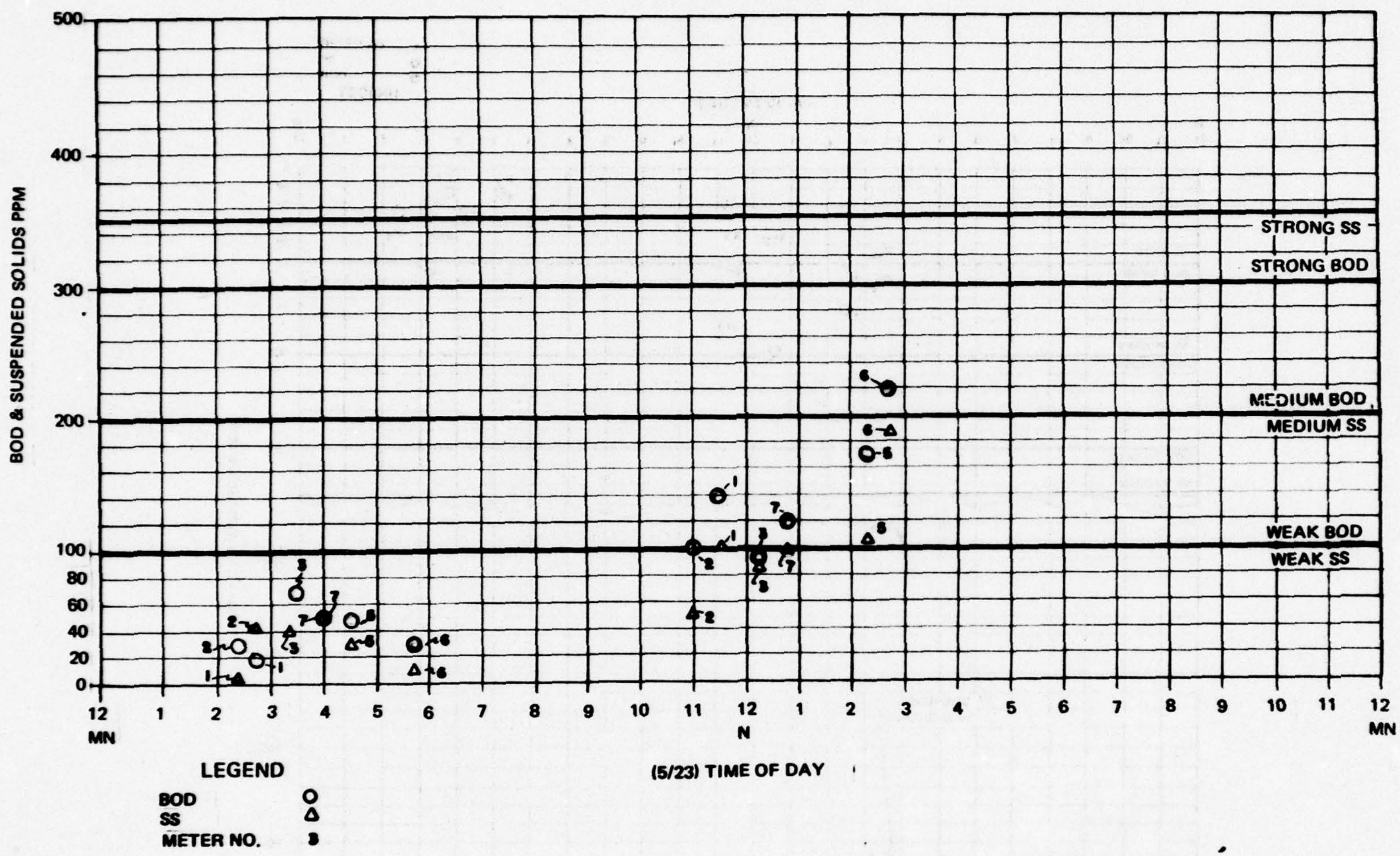

FIG. A-4 MAY 23, 1973 SAMPLE RESULTS BOD & SUSPENDED SOLIDS

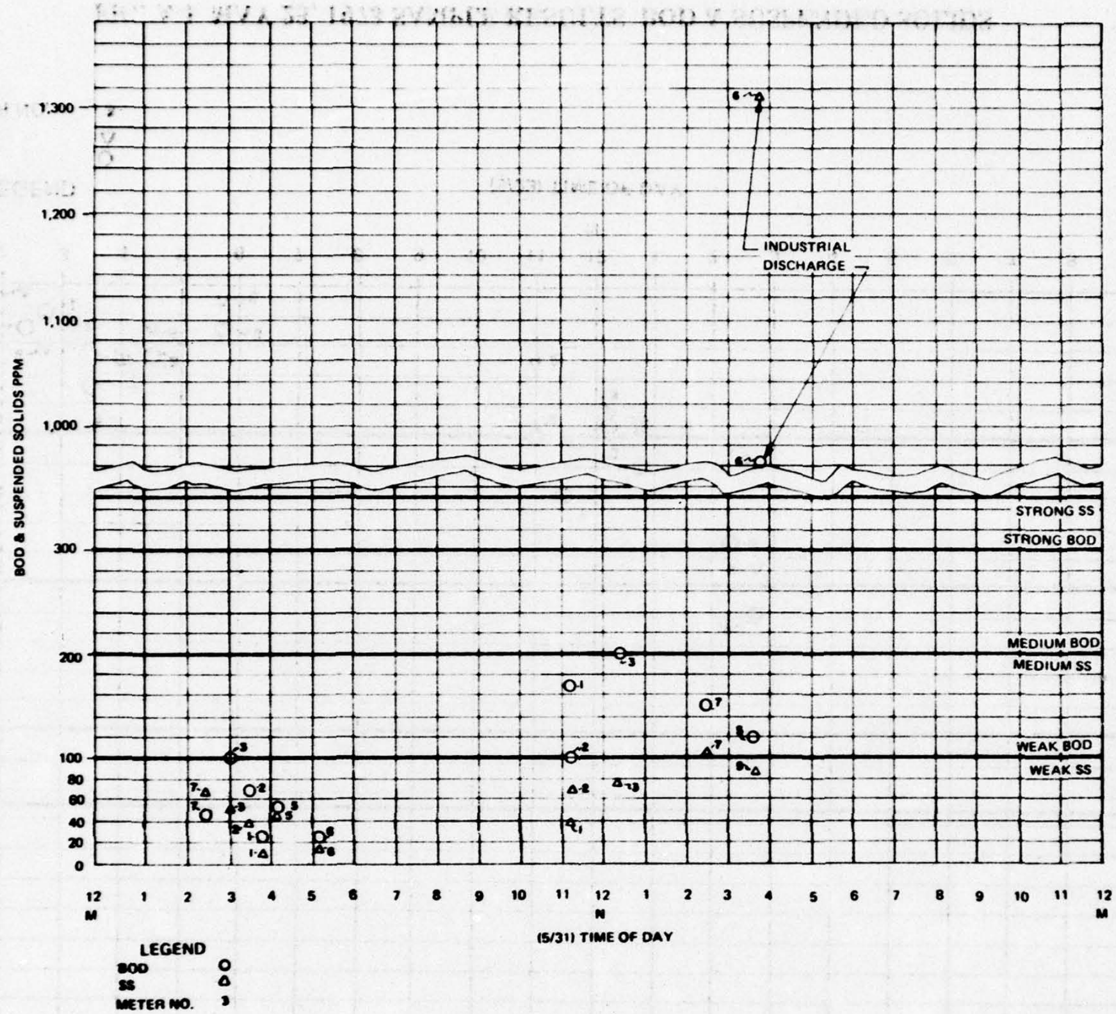

FIG. A-5 MAY 31, 1973 SAMPLE RESULTS BOD & SUSPENDED SOLIDS

depth was continuously recorded on a chart which was rotated by a spring-activated time clock. The early morning flows were our prime concern since most, if not all, of this flow was considered to be infiltration.

This depth of flow was converted to a rate of flow using Manning's Equation with a friction factor of n = .015 for old and middle age sewers and n = .013 for new sewers.

Infiltration Rate Basis

Peak Infiltration. The infiltration rate can be evaluated based on the cumulative lengths and average size of sewer pipe tributary to the measurement. For instance, the figure of 500 gallons per mile per inch diameter has been used as allowable infiltration in average ground conditions. This, however, is not acceptable unless a complete accounting of all lengths and sizes of sewers is available for all EMMA sewer locations.

An alternative to the above method is to base the infiltration rate on the tributary area (in acres) served by the sewerage system as shown on Figure A-1.

The early morning flows metered in this study were divided by their respective tributary areas and each point was plotted on an infiltration rate chart. The results of each collection system were evaluated by comparing the plotted point with typical curves.

Average Infiltration. The average infiltration allowances were based on an allowance added to the per capita sewage flow allowances.

Peak Infiltration Measurements Evaluation

The wet season measurements were evaluated and compared to the design curves normally used as described in the following subsection for each measurement point.

Wakefield (Old System). The percent of new, middle age and old sewers in the community are respectively 33, 17 and 50. To obtain the total flow from this community, it was necessary to meter at two locations on the Melrose-Wakefield town line in the Melrose Highland area.

Location No. 1 is a 12-inch diameter vitrified-clay sewer which was completed around 1897 in Greenwood Street, Melrose. This sewer collects sewage from approximately 75 acres in a residential area where single-family homes

predominate in the southwest sector of Wakefield. This location was metered to provide 21 days of flow information as shown in Table A-4.

TABLE A-4. WET SEASON INFILTRATION RATES MEASURED AT WAKEFIELD METER NO. 1

Date	Rainfall, in.	Flow, cfs	Infiltration rate, gad	Comments
4/26	.84			
4/27	.80	.23	1,980	
4/28	.11	.38	3,270	High
4/29	.01	.29	2,500	
4/30	0	.31	2,670	
5/1	Trace	.27	2,330	
5/2	.01	.29	2,500	
5/3	.08	.27	2,330	
5/4	.05	.26	2,240	
5/5	.01	.26	2,240	
5/6	.01	.26	2,240	
5/7	0	.21	1,810	
5/8	Trace	.23	1,980	
5/9	.93	.30	2,590	
5/10	Trace	.27	2,330	
5/11	.39	.23	1,980	
5/12	.01	.30	2,590	
5/13	Trace	.32	2,560	
5/14	0	.23	1,980	
5/15	.19	.29	2,500	
5/16	.39	Meter	Malfunction	
5/17	0			
5/18	.32			
5/19	0			
5/20	.23			
5/21	.93			
5/22	.03			
5/23	0	.29	2,500	
5/24	0	Meter	Malfunction	
5/25	Trace			
5/26	0			
5/27	0			
5/28	.26			
5/29	.28			
5/30	0			
5/31	.30	.19	1,640	Low

The minimum flows at this location occurred between the hours of 2:00 a.m. and 4:00 a.m. and the infiltration ranged between 1,640 and 3,270 gad with an average peak of 2,320 gad as shown on Figure A-6.

The average peak value of 2,320 gad was 320 gad greater than the 2,000 gad infiltration rate used in the design of new sewers and the maximum value measured, 3,270 gad, is below the allowance of 4,350 gad for old sewers. The actual early morning flows ranged from 0.19 to 0.38 cfs. The low flow occurred during a dry spell and the high flow after two days of relatively heavy rain.

Location No. 2 is a 30-inch diameter "portland brick" sewer completed around 1901 in the Boston and Maine Railroad right-of-way in Melrose. This trunk sewer serves approximately 2,050 acres in Wakefield which comprises the remainder of the town with the exception of a small area in the northwestern corner that discharges into the MDC's Reading Pump Station. Eleven days of flow information, as shown in Table A-5, was compiled at this location which consists of approximately 60 percent residential, 6 percent commercial, and 7 percent industrial land use. The early morning flows were believed to be infiltration.

The minimum flows at this location occurred between the hours of 3:00 a.m. and 7:00 a.m. and the infiltration ranged between 1,950 and 3,020 gad with an average peak value of 2,370 gad as shown on Figure A-7. These values indicate a high infiltration rate typical of old systems. A further explanation for this high value is that a substantial length of this sewer runs through a swamp area.

The actual early morning flows ranged from 6.19 to 9.59 cfs with the lower flows following a dry period and the higher flows following a period of rain.

<u>Lexington (New System)</u>. To obtain the total flow from Lexington, it was necessary to meter at two locations called Location No. 4 and 5. To complicate the situation, two pumping stations located in Bedford (New System) discharge into the Lexington collection system.

Location No. 4 on the Lexington Branch sewer is a 33-inch diameter reinforced-concrete pipe constructed around 1948. The pipe is located in the Boston and Maine Railroad right-of-way at the Arlington-Lexington town line, and picks up the majority of the flow from Lexington plus the flow from Bedford's two pumping stations.

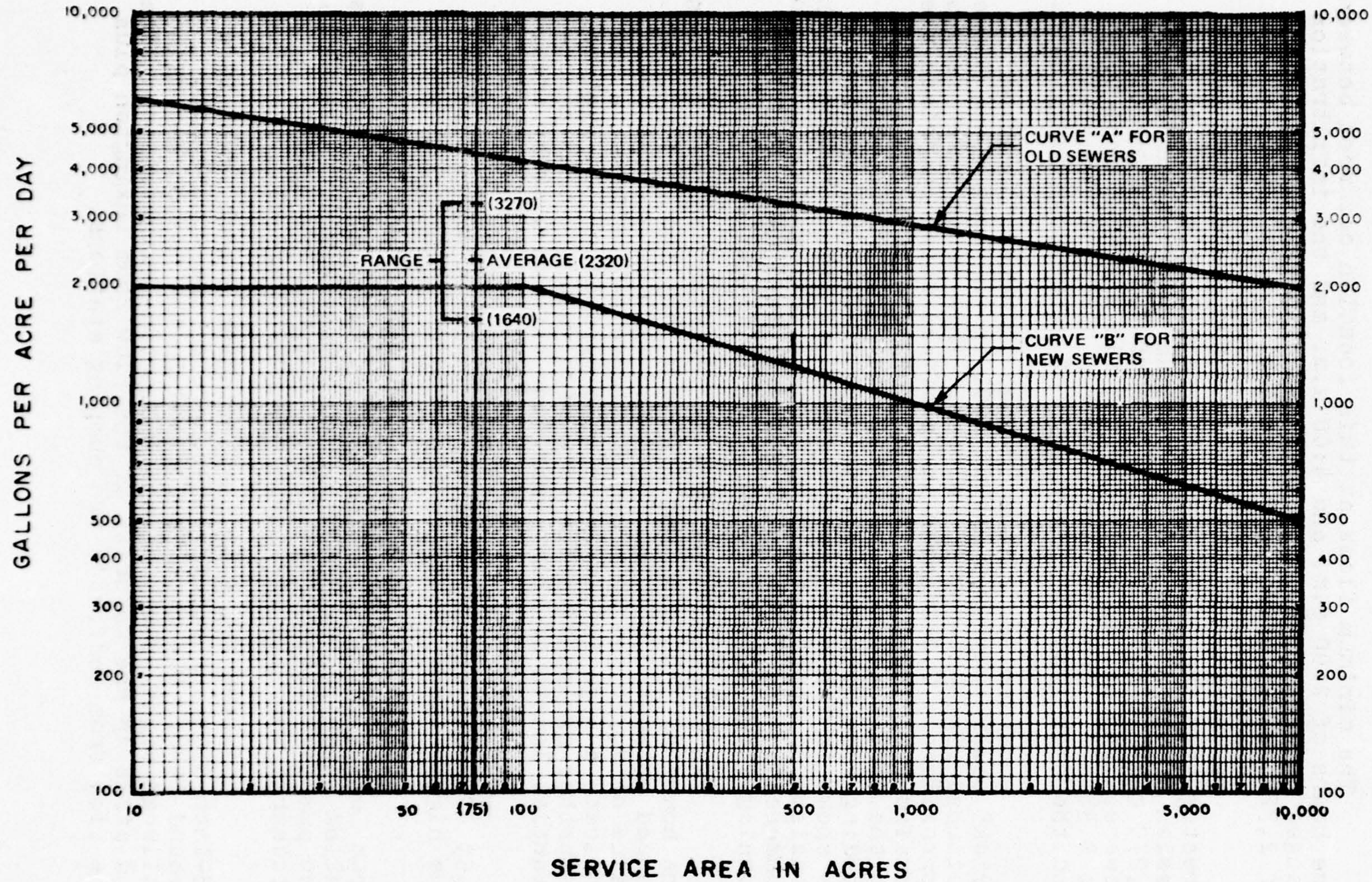

FIG. A-6 WET SEASON INFILTRATION ANALYSIS AT WAKEFIELD METER NO. 1

TABLE A-5. WET SEASON INFILTRATION RATES
MEASURED AT WAKEFIELD METER NO. 2

Date	Rainfall, in.	Flow, cfs	Infiltration rate, gad	Comments
5/2	.01			
5/3	.08			
5/4	.05	7.3	2,300	
5/5	.01	7.3	2,300	
5/6	.01			
5/7	0			
5/8	Trace	7.99	2,520	
5/9	.93			
5/10	Trace	7.12	2,243	
5/11	.39			
5/12	.01	6.19	1,950	Low
5/13	Trace	7.48	2,360	
5/14	0	7.48	2,360	
5/15	.19			
5/16	.39	7.48	2,360	
5/17	0	7.74	2,440	
5/18	.32	Meter Malfunction		
5/19	0			
5/20	.23			
5/21	.93			
5/22	.03			
5/23	0	9.59	3,020	High
5/24	0	Meter Malfunction		
5/25	Trace			
5/26	0			
5/27	0			
5/28	.26			
5/29	.28			
5/30	0			
5/31	.30	7.12	2,240	

Location No. 5 is a 20-inch diameter vitrified-clay sewer which was constructed around 1933 and located just below the Arlington-Lexington town line in the Boston and Maine Railroad right-of-way.

Flow information from these two locations was limited because large quantities of solids and debris continuously fouled the meters causing malfunctions.

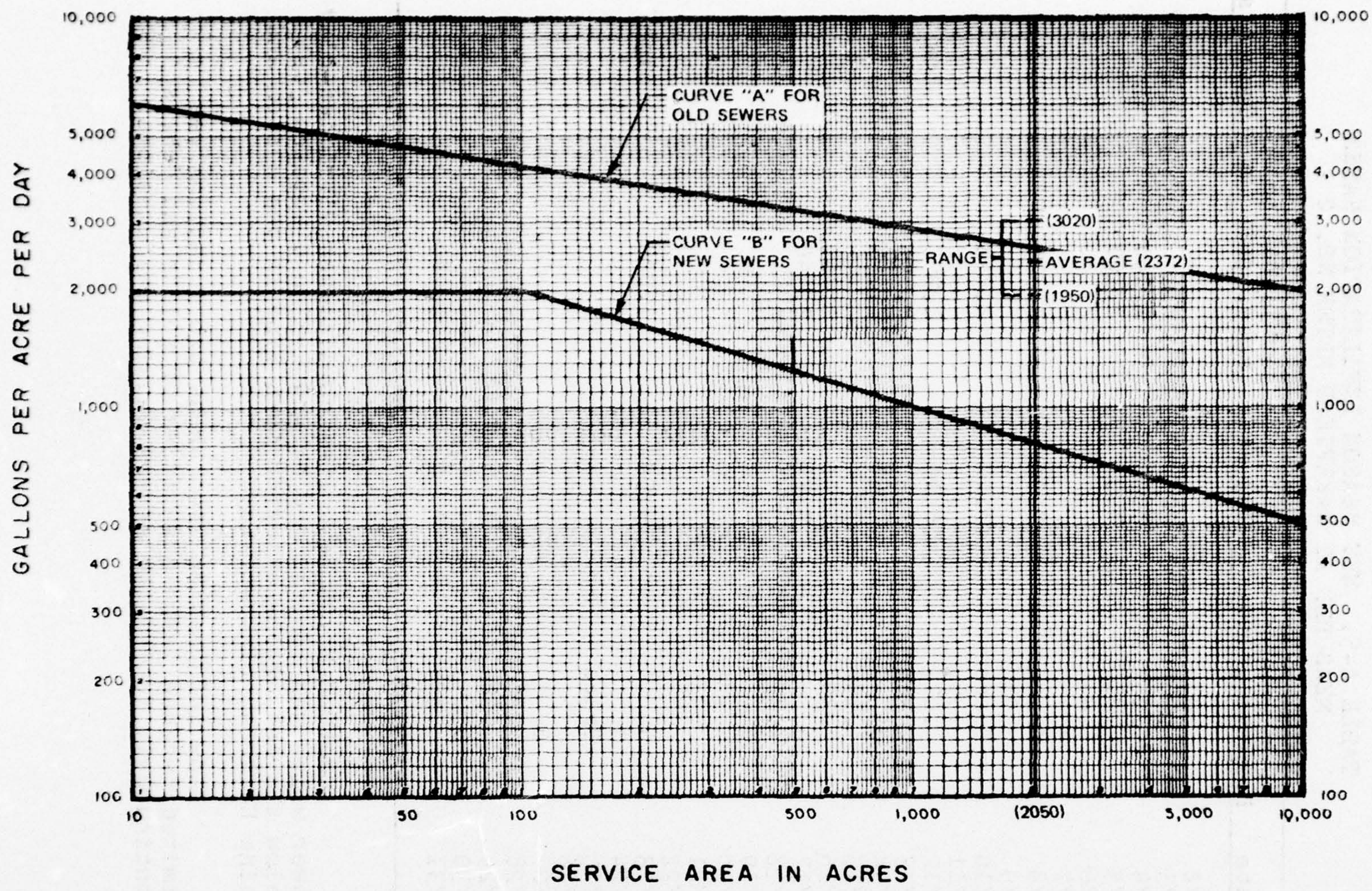

FIG. A-7 WET SEASON INFILTRATION ANALYSIS AT WAKEFIELD METER NO. 2

The total tributary area including Bedford is approximately 5,800 acres. Of this, 74 percent is Lexington, 21 percent Bedford and another 5 percent Hanscom Air Field in Bedford.

Reliable flows were obtained only during May 2, 3 and 4 in 1973. As shown in Table A-6, the infiltration rates average about 806 gad which is shown on Figure A-8 supports the use of the new sewer curve for Lexington considering that the above infiltration rates combine Lexington and Bedford which also has a new system. It must be noted, however, that when our field party visited Bedford's Great Road Pumping Station, they noted that during periods of heavy rain, an overflow pipe discharges a portion of the flow directly into the Shawsheen River.

From the depth of flow charts, it can be seen that for approximately eight days, there appears to be an oscillation of the early morning flows between 2:00 a.m. and 7:00 a.m. on Meter No. 4. This oscillation occurs at equal intervals indicating that either the Hanscom Air Force Base or the Great Road pumping stations were coming on line during this period.

TABLE A-6. WET SEASON INFILTRATION RATES MEASURED AT LEXINGTON METERS NO. 4 AND 5

Date	Rainfall, in.	Flow, cfs	Infiltration rate, gad	Comments
5/2	.02	2.83	757	Low
5/3	.14	3.12	833	High
5/4	Trace	3.10	827	
5/3	-	3.12	1,100	Lexington only

On the Meter No. 4 chart dated May 2, 1973, we computed the flow at the low points of the oscillations and considered this flow, combined with the flow from Meter No. 5, to be infiltration coming only from Lexington. This rate amounted to 1,100 gad which falls about midway between the old and new sewer curves. This is reasonable for the system composed of new, middle age and old sewers, respectively, as 54, 21 and 25 percent and bears out the justification for a middle age sewer curve.

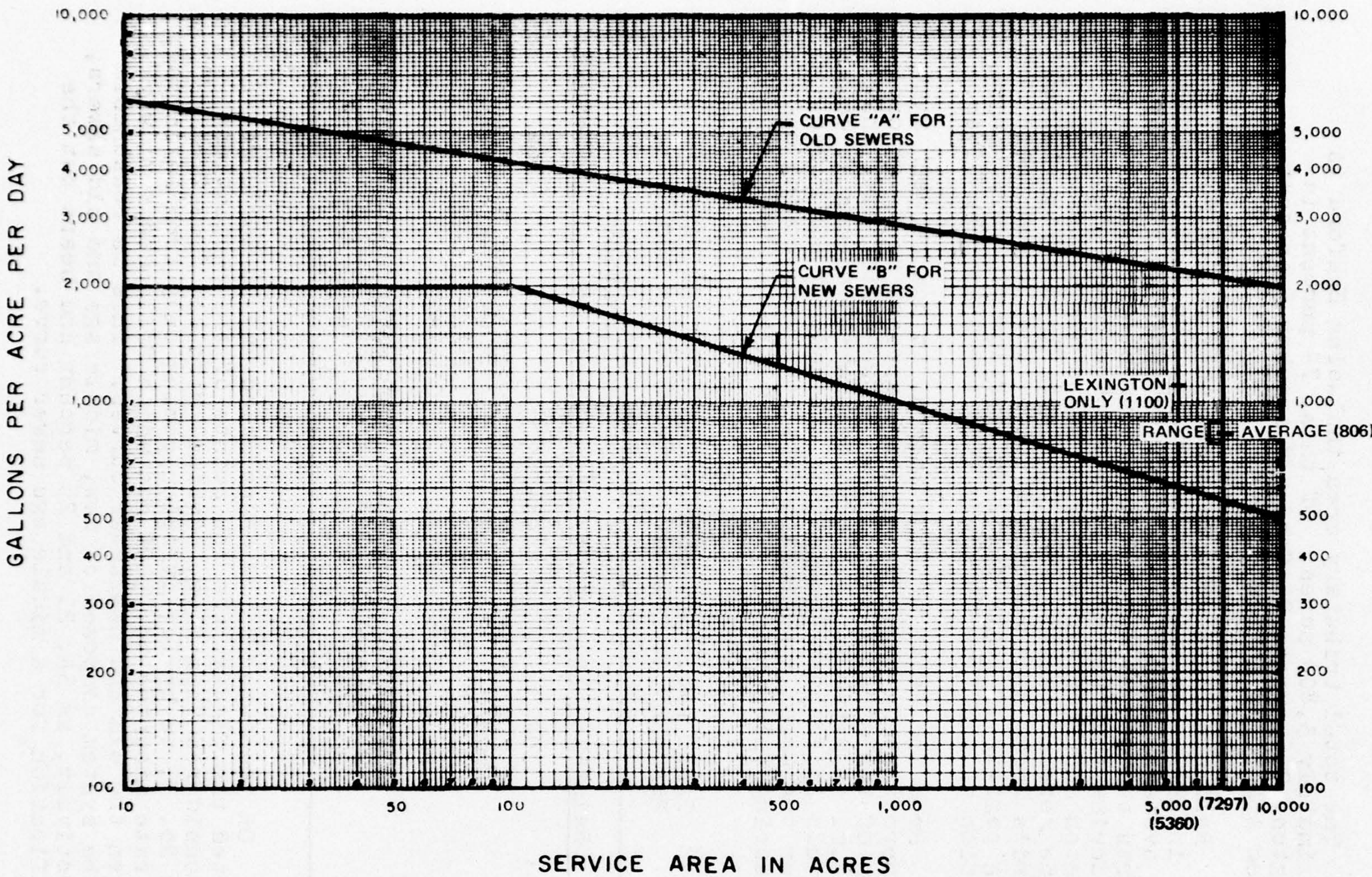

FIG. A-8 WET SEASON INFILTRATION ANALYSIS AT LEXINGTON METER NOS. 4 & 5

Westwood (New System). This community discharges the total flow through the Westwood Extension Sewer which at the metering point was a 30-inch diameter reinforced-concrete pipe constructed around 1960. Meter No. 6 located approximately 1,100 feet from the Westwood-Norwood line recorded 13 days of useful flow information. The sewered area from Westwood was found to be approximately 600 acres, of which 57 percent of the developed area is zoned residential, nine commercial, and nine industrial. Thus, Westwood was considered as a predominately residential community.

The minimum flows occurred between the hours of 2:00 a.m. and 7:00 a.m. and the minimum peak infiltration rate ranged between 576 and 960 gad averaging to 725 gad as shown on Figure A-9. Here again, the low number relates to flow during no rain and the high to rainy weather flow as shown in Table A-7. The sewage system age is entirely new, supporting the new sewer curve.

Stoughton (Middle-Age System). This community discharges its total sewage flow through the Stoughton Extension Sewer which at the metering point is a 20-inch diameter Akron pipe constructed around 1932. Meter No. 7 located approximately 250 feet downstream of the Canton-Stoughton town line, recorded 15 days of flow information. The tributary area from Stoughton is approximately 1,000 acres. Of this, approximately 55 percent is residential. Thus, we considered Stoughton predominantly a residential community.

The age of the sewer system is 35, 40 and 25 percent new, middle age and old, respectively.

The minimum flows shown in Table A-8 occurred between the hours of 1:00 a.m. and 6:30 a.m. The peak infiltration rate ranges from 740 to 1,820 gad with the average of the values at 1,175 gad as shown on Figure A-10. The average infiltration rate was approximately 200 gad above the new sewer curve indicating that for middle age sewers, an additional curve between curves "A" and "B" should be established.

Burlington (New System). This community has an entirely new sewer system which connects into the Woburn collection system which in turn discharges into the Metropolitan Sewerage District at the Woburn-Winchester town line. The Burlington collection system discharges its sewage through one 24-inch diameter reinforced-concrete pipe at the Burlington-Woburn town line. Upstream of the

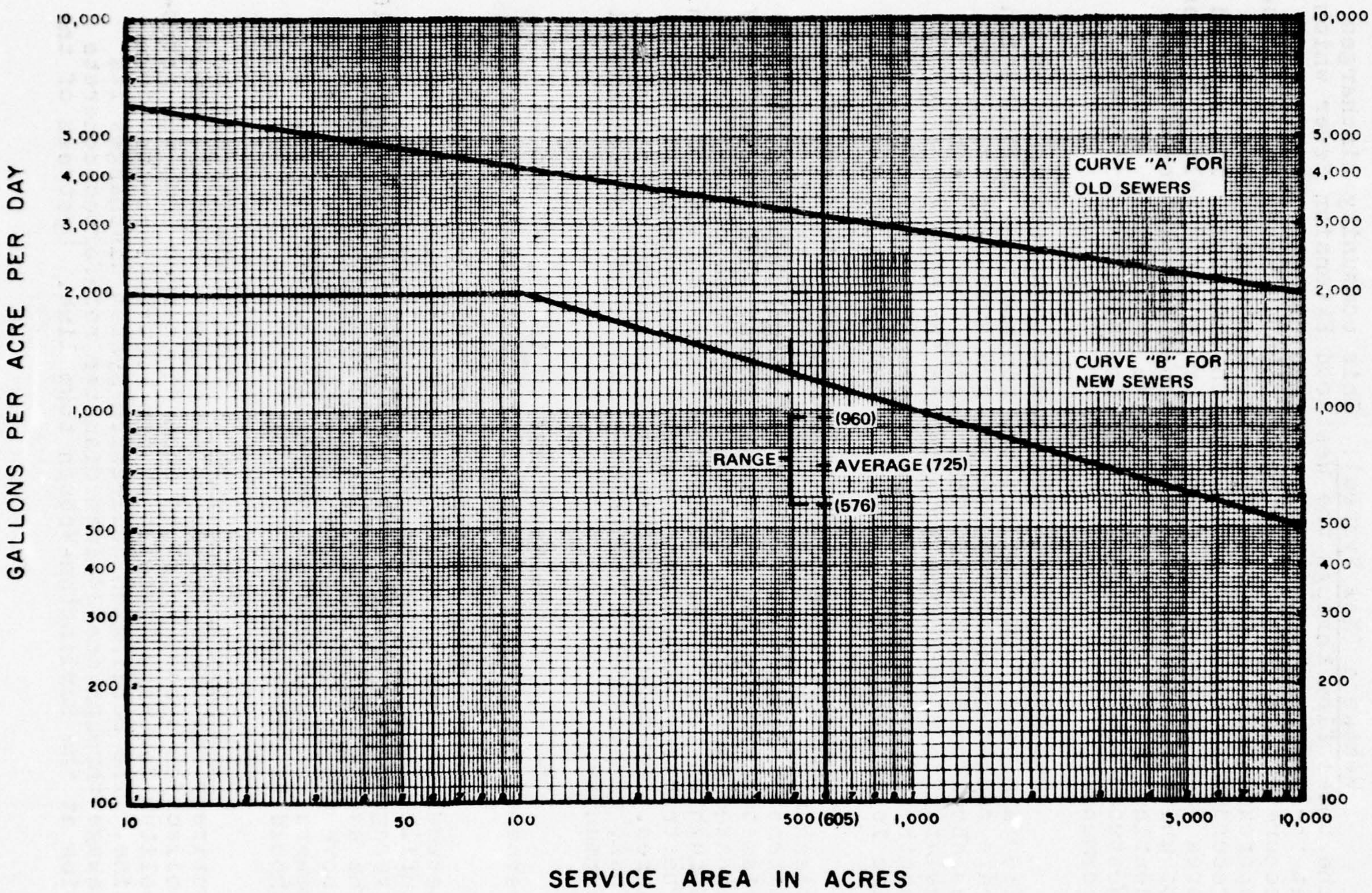

FIG. A-9 WET SEASON INFILTRATION ANALYSIS AT WESTWOOD METER NO. 6

TABLE A-7. WET SEASON INFILTRATION RATES
MEASURED AT WESTWOOD METER NO. 6

Date	Rainfall, in.	Flow, cfs	Infiltration rate, gad	Comments
4/27	.88			
4/28	.49			
4/29	.07	.9	960	High
4/30	Trace	.9	960	
5/1	0	.54	576	Low
5/2	Trace	.8	853	
5/3	0	.62	661	
5/4	.08	.54	576	
5/5	0	.62	661	
5/6	0	.62	669	
5/7	0			
5/8	0	.54	576	
5/9	.07	.54	576	
5/10	.47	.8	853	
5/11	.09			
5/12	.79	.68	725	
5/13	Trace			
5/14	0			
5/15	0			
5/16	.49			
5/17	Trace			
5/18	.05	Meter Malfunction		
5/19	.11			
5/20	0			
5/21	1.09			
5/22	.03			
5/23	0	.68	725	
5/24	0			
5/25	0			
5/26	Trace			
5/27	Trace			
5/28	0			
5/29	.27			
5/30	0			
5/31	.27			

town line, the interceptor splits into two 24-inch diameter conduits known as the Horn Pond and the Winn Street Trunk sewers. Meter No. 3 was installed on the Winn Street Trunk Sewer which runs northeasterly from the point of discharge at the town line and collects flow from approximately 940 acres or about one fourth of the sewered area.

TABLE A-8. WET SEASON INFILTRATION RATES MEASURED AT STOUGHTON METER NO. 7

Date	Rainfall, in.	Flow, cfs	Infiltration rate, gad	Comments
4/27	.82			
4/28	.66			
4/29	0	2.40	1,430	
4/30	0	2.40	1,430	
5/1	0	1.60	950	
5/2	0	1.60	950	
5/3	Trace	1.60	950	
5/4	.08	1.60	950	
5/5	?	2.18	1,300	
5/6	Trace	2.40	1,430	
5/7	0	1.98	1,180	
5/8	0	1.60	950	
5/9	.87	1.25	740	Low
5/10	.02	1.98	1,180	
5/11	.99	1.78	1,060	
5/12	.02	3.06	1,820	High
5/13	0	2.18	1,300	

The Winn Street Trunk Sewer at the meter location is a 24-inch diameter reinforced-concrete pipe constructed in about 1967. The tributary land use is a mixture of residential and commercial with the residential area being the larger.

Thirteen days of flow data was collected during metering as shown in Table A-9. The minimum flow occurred between the hours of 2:00 a.m. and 7:00 a.m. The peak infiltration rate ranges from 131 to 379 gad with an average rate of 252 as shown on Figure A-11. This average infiltration rate fell well below the curve for new sewers.

Additional Communities Analyzed for Peak Infiltration

Nine additional communities shown in Table A-10 were evaluated for infiltration on the basis of data from past engineering studies. This information is plotted on Figure A-12 for comparison.

Average Infiltration Measurements Evaluation

General. Early morning flow measurements were not recorded every month of the year, thus the full duration

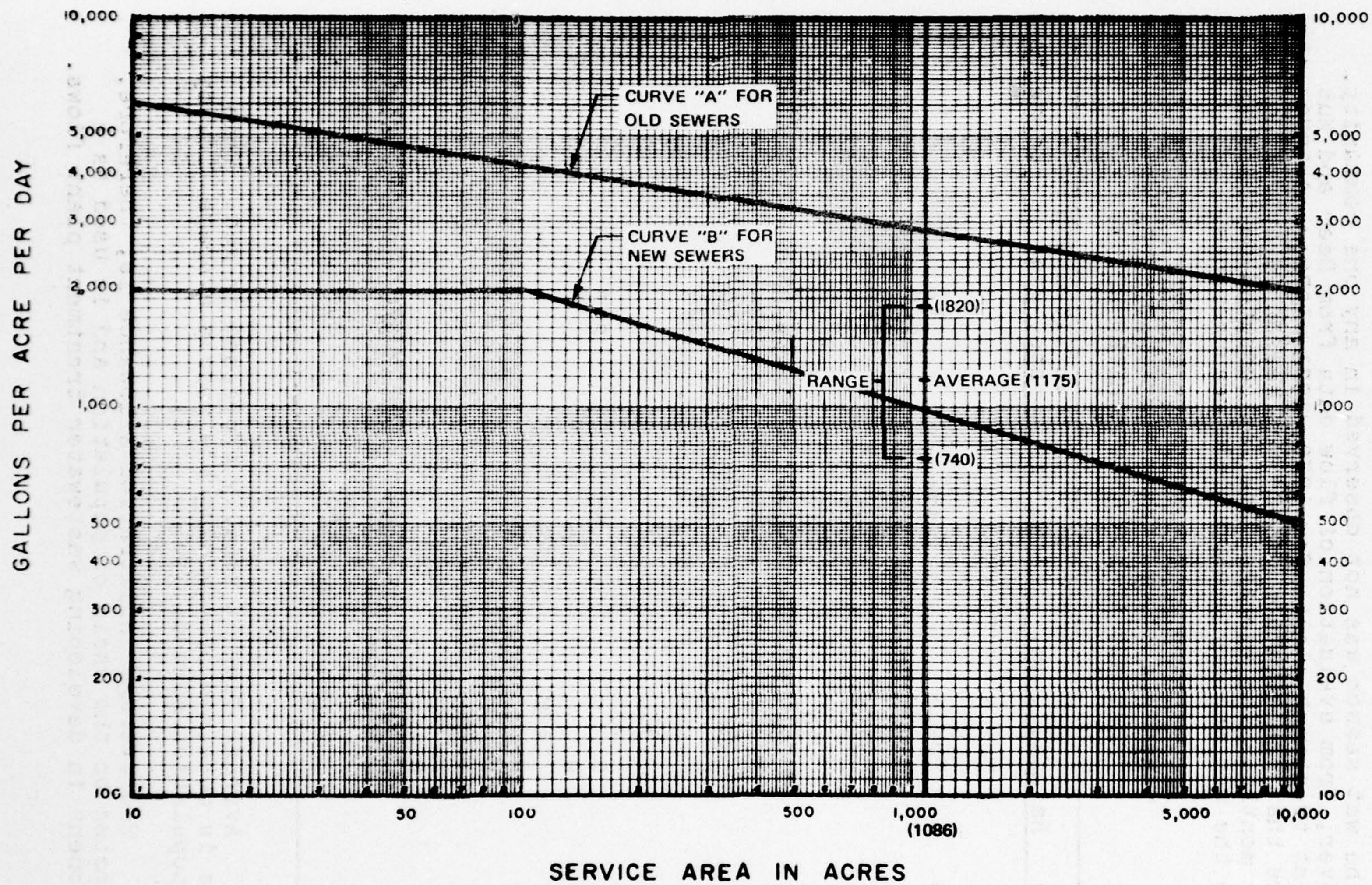

FIG. A-10 WET SEASON INFILTRATION ANALYSIS AT STOUGHTON METER NO. 7

of the wet season was not observed in any one community. However, from evaluation of flow data from Deer and Nut Islant treatment plants for 1970, 1971, 1972, and 1973, it shows that the duration of the wet season is approximately four months. The average flow was computed on this basis from the wet and dry season field measurements.

TABLE A-9. WET SEASON INFILTRATION RATES MEASURED AT BURLINGTON METER NO. 3

Date	Rainfall, in.	Flow, cfs	Infiltration rate, gad	Comments
5/8	Trace			
5/9	.93			
5/10	Trace	.19	131	
5/11	.39	.43	297	
5/12	.01	.29	200	
5/13	Trace	.35	241	
5/14	0	.35	241	
5/15	.19	.19	131	Low
5/16	.39	Meter	Error	
5/17	0	.40	275	
5/18	.32	.29	200	
5/19	0	.48	331	
5/20	.23			
5/21	.93			
5/22	.03			
5/23	0	.43	297	
5/24	0			
5/25	Trace			
5/26	0			
5/27	0			
5/28	.26			
5/29	.28			
5/30	0			
5/31	.30	.55	379	High
6/1				
6/2		.43	297	

Average flow is usually expressed in gcd. This value is obtained by dividing the yearly average flow by the population served.

The average infiltration allowance is, therefore, estimated on the basis of population and is used as a component in developing wastewater treatment plant flows.

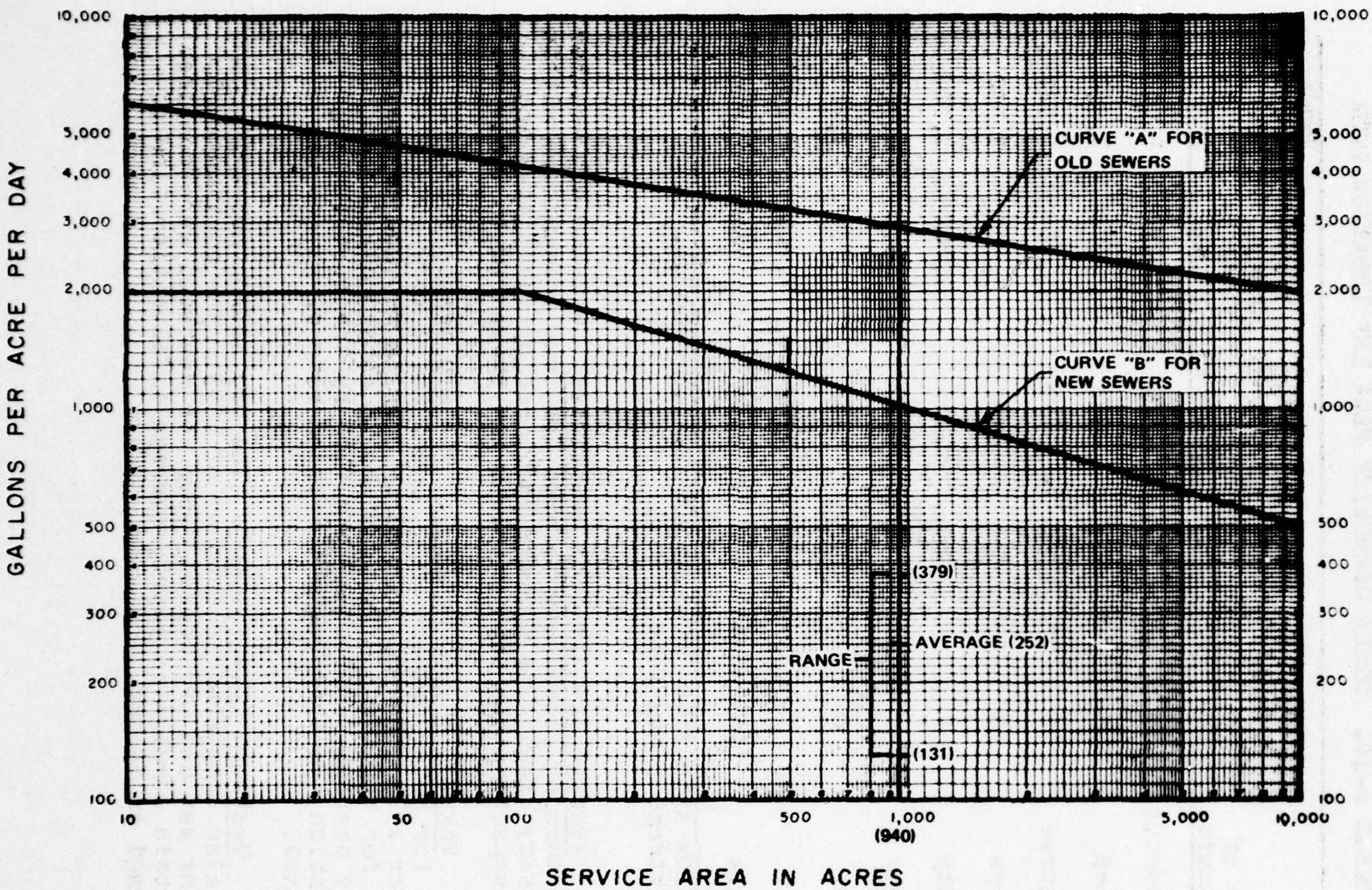

FIG. A-11 WET SEASON INFILTRATION ANALYSIS AT BURLINGTON METER NO. 3

TABLE A-10. OTHER COMMUNITY PEAK INFILTRATION DATA

Name of community	System age in % New	MA	Old	Year flows were observed	Tributary area in acres	Peak infiltration rate, gad
Marlborough	10	10	80	1969	1,250	2,000
Concord	5	10	85	1971	670	1,490
Braintree	58	15	26	1972	1,900	1,120
Danvers	33	33	34	1967	3,500	1,100
Peabody	0	0	100	1967	2,800	1,700
Beverly	30	20	60	1967	890	2,900
Salem	0	0	100	1967	1,150	3,700
Quincy	5	9	86	1973	7,400	2,160(1)
Walpole	44	4	52	1965	760	1,050(2)

1. Flow data from MDC pumping station records.
2. Extremely dry year.

Average Infiltration Quantities. Wet and dry weather early morning flows were metered for four communities within the study area. The average infiltration quantities and the respective per capita values are presented in Table A-11.

Wakefield (Old System). The dry season measurements for meter locations No. 1 and No. 2 were completed in October 1973. The minimum early morning wet and dry season flows for Wakefield were combined to obtain a weighted yearly average. Dividing this flow by the contributing population, an average infiltration rate of 91 gcd was obtained.

Westwood (New System). The dry season measurements were also completed in October of 1973. The minimum early morning wet and dry season flows for Westwood were combined to obtain a weighted yearly average infiltration flow of 0.32 mgd or 74 gcd.

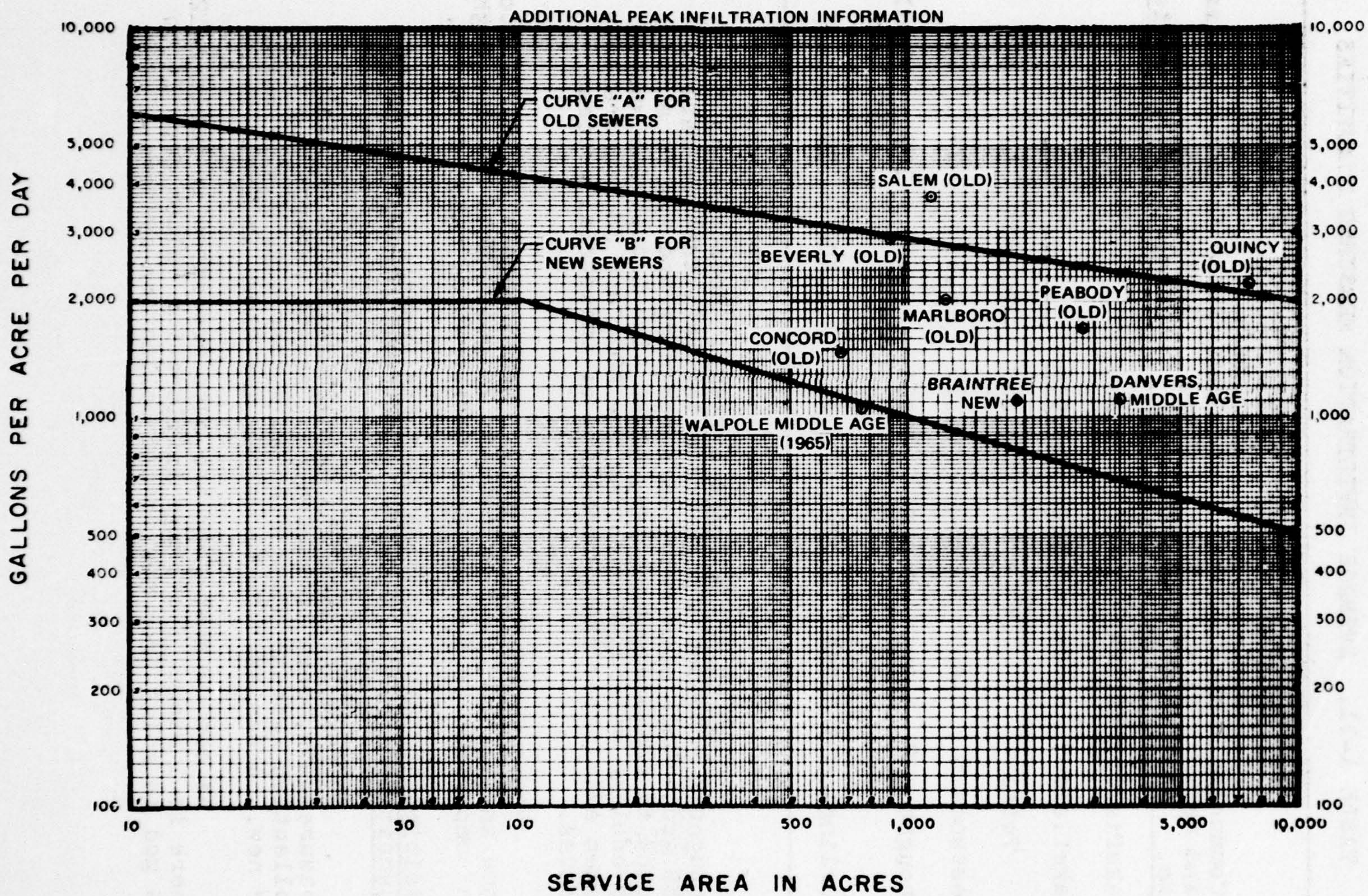

FIG. A-12 PEAK INFILTRATION RATES FOR SELECTED COMMUNITIES

TABLE A-11. AVERAGE INFILTRATION MEASURED QUANTITIES

Community and meter No.	Wet season minimum flow, mgd	Dry season minimum flow, mgd	Yearly average minimum flow, mgd	Population served	Infiltration rate, gcd	Class of system
Wakefield 1	0.174	0.080	0.104			
Wakefield 2	4.863	0.962	1.936			
Total			2.040	22,350	91	Old
Westwood 6	0.439	0.280	0.319	4,330	74	New
Stoughton 7	1.276	0.995	1.065	5,640	189	Middle age
Burlington 3	0.236	0.278	0.267	3,400	79	New

Stoughton (Middle-Age System). Measurements for Stoughton provided a high estimated infiltration rate of 189 gcd. This high value is surprising and can be attributed to measurement errors, night time industrial wastes or cooling water. Inspecting the BOD_5 and SS measurements taken eliminates the probability of industrial process wastes.

Burlington (New System). Measurements for Burlington show an average low flow rate of 79 gcd. This appears high in comparison to the low peak infiltration rates measured.

Additional Communities Analyzed for Average Infiltration Quantities

Average infiltration quantities, based on field measurements, were extracted from recent reports and the collection systems classified as either old, middle aged, or new. A summary of the values are shown in Table A-12.

As can be seen from the data presented in Table A-12, there is a range of average infiltration values from 24 to 94 gcd in going from new to old collection systems.

TABLE A-12. OTHER COMMUNITY AVERAGE INFILTRATION DATA

Name of community	System age, % New	MA	Old	Average infil-tration, mgd	Popula-tion served	gcd	Age classifi-tion
Wellesley	20	27	53	1.78	22,700	78	Old
Lynn	0	0	100	8.1	89,380	90	Old
Peabody	0	0	100	2.0	24,000	83	Old
Saugus	33	33	34	0.8	14,000	57	M.A.
Beverly	20	20	60	2.0	33,770	59	Old
Marblehead	10	10	80	1.3	20,230	64	Old
Salem	0	0	100	2.2	38,920	55	Old
Ipswich	100	0	0	0.1	4,190	24	New
Danvers	33	33	33	0.7	18,300	38	M.A.
Concord	5	10	85	0.56	6,000	94	Old

Selected Infiltration Rates

On the basis of measurements data and past experience, the selected peak design areas along with a summary of measured infiltration rates are shown on Figure A-13.

Average infiltration rates for new, middle age, and old sewers were selected as 30, 60 and 90 gcd.

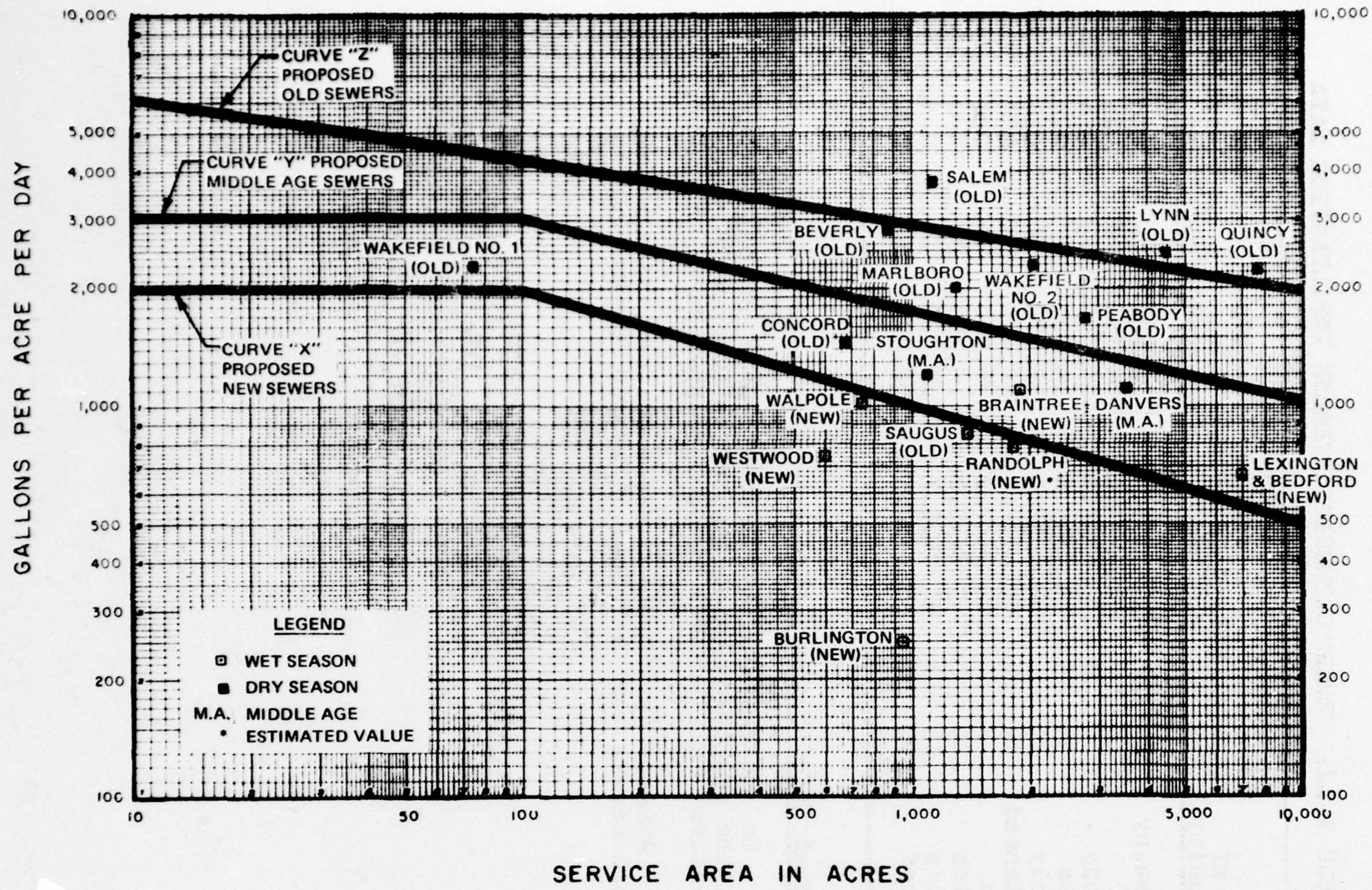

FIG. A-13 PEAK INFILTRATION RATES

APPENDIX B

SALT WATER INTRUSION ANALYSIS

General

Salt water intrusion into the collection systems contributing to the Deer Island Treatment Plant is a major problem which has been recognized as such for many years. It is believed that inoperative or broken tide gates are the source of most of the salt water intrusion.

Previous Studies

In our report with Greeley & Hansen to the Special Commission established by the Legislation in 1938 upon "Sewerage and Sewage Disposal in Metropolitan Boston," dated March 1939, sampling and analyses of sewage at the three main sewer outlets of Metropolitan Boston were made by the State Department of Public Health. These were the Boston Main Drainage and the North and South Metropolitan District outfalls. The chloride content at each location is shown in Table B-1 with the computed quantities of salt water:

TABLE B-1. SALT WATER INTRUSION IN 1935-1936

Sewage system	Average flow, mgd	Average chlorides, ppm(1)	Estimated salt water, mgd
Boston Main Drainage	75.3	4,080	20
North Metropolitan District	82.9	3,280	17
South Metropolitan District	86.5	198	Negligible

1. ppm = parts per million.

From the above table, we can see that on the average a total estimated 37 mgd or approximately 27 percent of the 1935 flow from the Boston Main Drainage System was salt water and approximately 21 percent of the 1935 flow from the North Metropolitan District was salt water. The salt water entering the South Metropolitan District was negligible.

The "Water Quality Management Study, Boston Harbor, Projections of Population and Municipal Waste Loadings," September 1970, prepared by the Boston Harbor Water Quality Management Coordinating Group, also addresses the salt water intrusion problem. This study concluded that the average chloride content in sewage flow to the Deer Island Treatment Plant in 1969 was 3,690 ppm. The 1969 average measured flow, including salt water, to Deer Island was 279 mgd. From samples taken in 1967 of the Boston Harbor waters in the vicinity of the shore line, the average chloride content was found to be approximately 15,400 ppm. From this information, it was deduced that 24 percent of the measured flow to Deer Island was ocean water. This is an average daily salt water inflow of approximately 67 mgd.

Tide Gate Rehabilitation Program

A program of inspection and rehabilitation of all the tide gates connecting to the collection system tributary to the Deer Island Treatment Plant began June 10, 1970.

This rehabilitation program is in progress at this time.

Present Conditions

For the calendar year 1972, the average chloride content of the flow to the Deer Island Treatment Plant was 2,238 ppm as shown in Table B-2. The average measured flow, including salt water, was 348 mgd. Taking the chloride content of Boston Harbor at 15,000 ppm shows that 14 percent of the measured flow to the Deer Island Treatment Plant was ocean water. This is an average flow of approximately 49 mgd which is a 27 percent reduction from the 1969 salt water flow estimate.

Reviewing the average monthly quantities in Table B-2 shows that the highest average monthly flow of 434 mgd and the lowest chloride levels of 1,350 ppm occurred in March. This combination gives us an average salt water flow of 36.6 mgd which is one of the lowest monthly average during the year.

Conversely, the lowest average monthly flow of 304 mgd and one of the highest monthly chloride levels of 3,200 ppm occurred in October. This combination gives us an average monthly salt water flow of 63.6 mgd which is one of the highest monthly averages for the year.

TABLE B-2. 1972 AVERAGE MONTHLY QUANTITIES OF SALT WATER INFLOW AT THE DEER ISLAND TREATMENT PLANT

Month	Total flow, mgd	Chloride content, mg/L	Salt water inflow mgd	Salt water inflow %
January	306	2,100	40.6	13.2
February	318	2,300	47.3	14.8
March	434 (High)	1,350	36.6 (Low)	8.4 (Low)
April	350	1,700	37.3	10.6
May	378	1,600	36.1	9.6
June	426	1,500	40.3	9.5
July	322	2,100	47.0	14.6
August	310	2,800	57.7	18.6
September	323	3,100	65.0	20.0
October	304 (Low)	3,200 (High)	63.6 (High)	21.1 (High)
November	372	2,700	63.4	17.1
December	392	2,400	51.0	13.0
Average for year	353	2,238	49.0	13.8

This is because the collection system flow itself regulates the quantity of salt water inflow. That is, when the collection system capacity is being used by a combination of sewage and stormwater as during wet periods, relatively small amounts of seawater enter the system. On the other hand, when there is no rainfall, seawater occupies the unused space. Given the right combination of low flows, high tides, etc., seawater inflow can get as high as 104 mgd (31 percent) as it did on August 7, 1972.

For a 10-month period (January-October) for 1973, salt water inflow at the Deer Island Treatment Plant is shown in Table B-3.

The highest daily value occurred on October 29 when the salt water inflow was 132 mgd or 38 percent of the total.

Tide Gate Elevations Relative to Tidal Range

Inspecting sewer maps of a sample of 42 tide gates in Boston showed that of the total 42 tide gates checked, 10 had controlling invert elevations below mean low water

and the remaining 32 tide gates had controlling invert elevations within the mean tidal range of Boston Harbor. Controlling invert elevations were selected as those where salt water will flow into the collection system and be transmitted to the MDC interceptors.

TABLE B-3. AVERAGE MONTHLY QUANTITIES OF SALT WATER INFLOW AT THE DEER ISLAND TREATMENT PLANT

Month	Total flow, mgd	Chloride content, mg/L	Salt water inflow mgd	Salt water inflow %
January	363	2,400	56	15.4
February	347	2,800	63	18.2
March	310	3,320	67	21.6
April	385	3,100	76	19.7
May	359	3,100	72	20.0
June	336	3,300	72	21.4
July	353	2,700	62	17.6
August	325	2,760	58	17.8
September	290	3,350	63	21.7
Cctober	279	4,288	78	28.0

The fact that all the tide gates checked have control invert elevations below or in the mean tidal range makes it clear that it is essential that the tide gates operate properly to stop the seawater from finding its way to the Deer Island Treatment Plant. If these gates remain open, the only limit on the quantity of salt water entering the system will be the salt water differential head on the system and the conduit size conducting the flow.

Salt Water Infiltration

Although damaged or inoperative tide gates are believed to be the main source of salt water intrusion, we suspect that seawater also enters the collection system by infiltrating the older sewers that are found bordering the coastline. To evaluate this impact, we metered and sampled at three locations in the Revere collection system along Revere Beach as shown on Figure B-1. Sewer lines leaving areas No. 2 and 3 which collected flows from the beach front area had relatively high chloride levels while the flow in the sewer lines from area

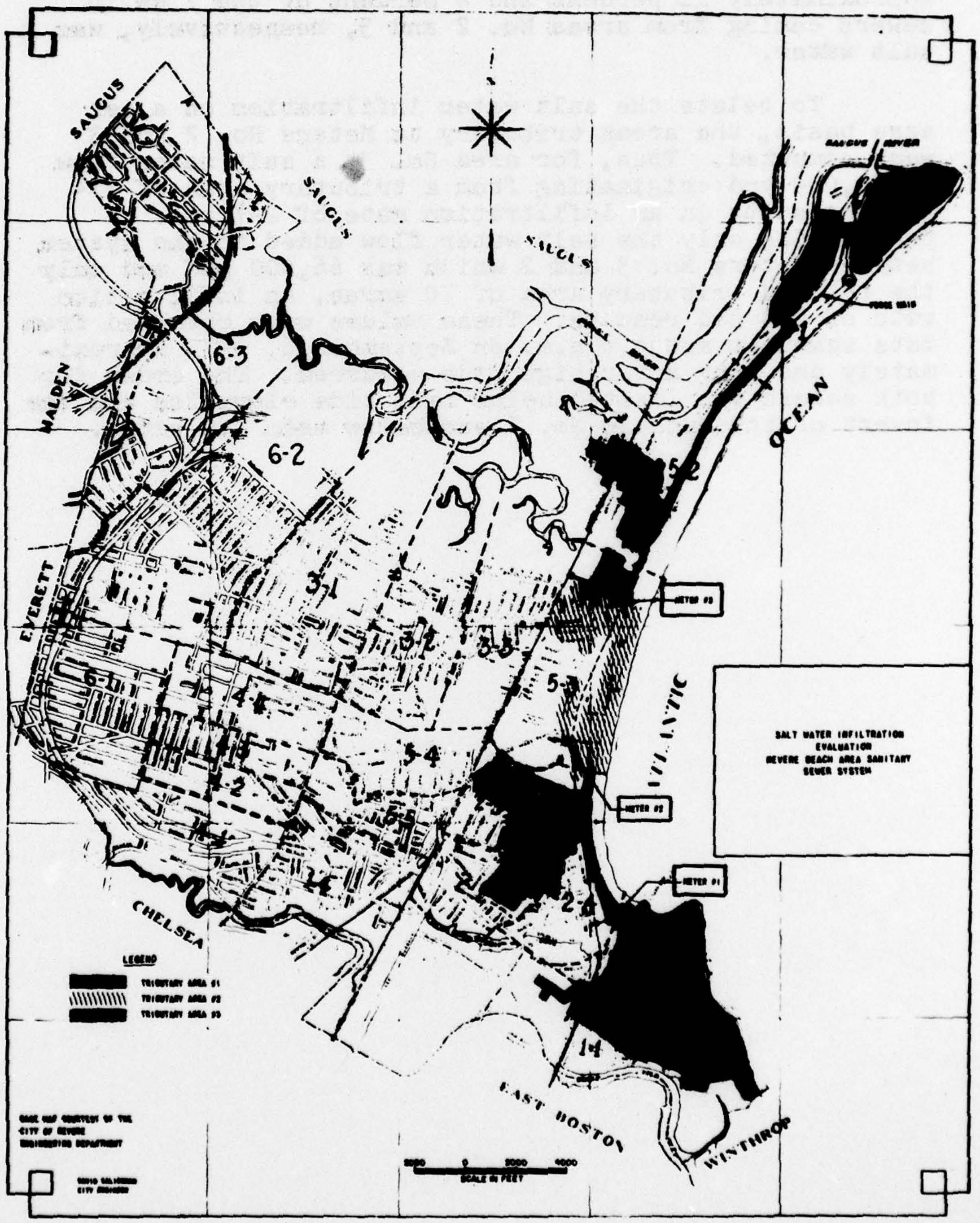

FIG. B-1 SALT WATER INFILTRATION EVALUATION REVERE BEACH AREA SANITARY SEWER SYSTEM

No. 1 had a chloride content below that of normal sewage. Approximately 11 percent and 6 percent of the flow in sewers coming from areas No. 2 and 3, respectively, was salt water.

To relate the salt water infiltration on a per acre basis, the areas tributary to Meters No. 2 and 3 were computed. Thus, for area No. 3, a salt water flow of 43,000 gpd originating from a tributary area of 174 acres results in an infiltration rate of 247 gad. Considering only the salt water flow added to the system between Meters No. 3 and 2 which was 66,000 gpd and only the related tributary area of 70 acres, an infiltration rate of 993 gad results. These values were obtained from data taken at about 8 a.m. on September 6, 1973 approximately one hour after high tide occurred. The crown for both sewers was located below mean tide elevation and the invert of the Manhole No. 2 was below mean low water.